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ABSTRACT

This manual, written in response to requirements of the Washington State legislature, focuses on practices which can be undertaken during the siting, design, construction, or renovation of a school, recommends practices to help ensure good indoor air quality during building occupancy, and suggests protocols and useful reference documents for investigating and handling indoor air quality complaints and problems. Sections cover: why indoor air needs management; the factors influencing indoor air quality; the basic strategies for good indoor air quality; the siting, designing, and constructing of schools for good indoor air quality; and the operating and maintenance of heating, ventilation, and air conditioning (HVAC) systems. Final sections examine air contaminant sources and control in classrooms, offices, and special use areas; and planning and management methods to maintain indoor air quality. Appendices provide the Washington State Department of Health School Indoor Air Quality Survey, and an HVAC Checklist. (GR)

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School Indoor Air Quality Best Management Practices Manual

February 1995

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Preface

The School Indoor Air Quality Best Management Practices Manual was prepared by the Washington State Department of Health, with financial assistance provided by the Office of the Superintendent of Public Instruction. The Manual was written in response to requirements of the Washington State Legislature.

The Manual was prepared between July 1994 and January 1995. During this period the Department of Health formed and consulted with a School Indoor Air Quality Advisory Committee, which provided valuable technical guidance and policy support.

The Department of Health encourages all users of the Manual to examine the concepts, recommendations, and procedures outlined in the Manual; evaluate their usefulness and effectiveness; identify any costs and obstacles to implementation; and describe any benefits received. Users of the manual are invited to report their findings to the Department of Health, Community Environmental Health Programs (refer to the address and phone number on the title page). Such information may be used to update and improve the Manual, and may assist in identifying training and technical assistance needs related to school indoor air quality.

It is important to recognize that the practices specified or recommended in this Manual include some that are already *required* by code or law, and others that are *recommendations* which may help promote good indoor air quality in schools. It is the responsibility of each school district and other users of the Manual to comply with applicable codes and laws--including those related to building, plumbing, electrical and mechanical systems, fire protection, safety, energy use, and environmental protection. However, all users of the Manual, including school districts, should evaluate the discretionary recommendations presented in this Manual, and adopt or promote those which, in their judgment, are relevant and applicable to their circumstances, and feasible to implement. In the event that any recommendations offered in this Manual are in conflict with any applicable codes or laws, such codes or laws shall take precedence.

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Section One: Introduction

The Manual's Purpose

This School Indoor Air Quality Best Management Practices Manual has been written to help prevent and reduce indoor air quality problems in Washington's schools. It is intended for schools serving students in kindergarten through grade twelve.

The Manual focuses on practices which can be undertaken during the siting, design, construction, or renovation of a school. Although the Manual focuses on new and renovated schools, it recommends practices to help ensure good indoor air quality during building occupancy. These practices affect operation and maintenance, repairs and minor construction, as well as the school's administrative organization and lines of communication.

The Manual also suggests protocols and useful reference documents for investigating and handling indoor air quality complaints and problems that arise. The broad scope of this Manual will allow it to be useful in managing indoor air quality issues in existing, older schools as well as newly-constructed or renovated buildings.

Causes for Poor Indoor Air Quality

Poor indoor air quality may have many causes: contaminated outdoor air brought into the building; building materials, furnishings and equipment; facility operation and maintenance practices; various activities of students, teachers, and staff; and heating, ventilation, and air conditioning (HVAC) systems and their operation. Problems that arise from indoor air may be more difficult to solve unless there is good communication among staff, teachers, students, parents, and other interested or affected groups.

The purpose of this School Indoor Air Quality Best Management Practices Manual is to promote practices which prevent or reduce the contamination of indoor air, thereby contributing to a safe, healthy, productive, and comfortable environment for students, teachers, and other school staff.

Who Will Use the Manual

Primary Users

The School Indoor Air Quality Best Management Practices Manual is primarily intended for use by:

- school administrators, teachers, school building administrative staff, and central administrative staff
- architects and engineers, and
- school facilities and maintenance personnel

To ensure accountability and appropriate use of the practices presented in this Manual, each school should appoint a *school indoor air quality coordinator* (IAQ coordinator). This function is described in *Section Four: Basic Strategies for Good Indoor Air Quality*, and *Section Eleven: Indoor Air Quality Planning and Management*.

Other Users

Other groups that have a significant interest in school indoor air quality issues and application of the best management practices include:

- students and their parents
- local school boards
- school site councils
- local health, building, and fire officials
- other contract providers of supplies, services, equipment, and facilities
- state agencies, including the Department of Health, the Office of the Superintendent of Public Instruction, the Department of Labor & Industries, the State Energy Office, and related organizations, including the School Facilities Cost Advisory Board.

The other contract providers identified above include companies that maintain HVAC systems, provide school supplies, and manufacture or supply construction materials, building furnishings and equipment.

It is important for school administrators and the IAQ coordinator to alert other potential Manual users and interested groups of the school's efforts to manage indoor air quality. The IAQ coordinator should work closely with other users of the Manual to ensure that as appropriate, the best management practices are followed during each phase of school development or renovation, and ultimately during school operation.

Organization and Content of the Manual

The remaining sections of this Manual (Sections Two through Twelve) address special topics related to indoor air quality in schools. These sections are briefly summarized below.

Section Two: Why Manage Indoor Air Quality?

The importance of managing school indoor air quality is discussed in *Section Two*. The consequences of poor indoor air quality are described--including the health symptoms and problems; strained relationships among parents, school administration and staff; and the increased liability and risks.

Section Three: Factors Influencing Indoor Air Quality

The factors that influence indoor air quality are described in*Section Three*. These factors include outside sources as well as building components, furnishings, equipment, supplies, and activities of students, teachers, and staff. Specific sources and types of contaminants, and associated comfort and health effects are defined.

Section Four: Basic Strategies for Good Indoor Air Quality

Section Four of the Manual discusses the six basic control methods for reducing the exposure of students and building staff to indoor air contaminants. In addition, this section explains the need to designate a school IAQ coordinator, and outlines the roles and responsibilities of the IAQ coordinator.

Section Five: Siting Schools for Good Indoor Air Quality

Section Five discusses key issues to consider when siting a school building. Environmental site assessments, and examination of climate, nearby sources of air emissions, and other environmental factors are suggested.

Section Six: Designing Schools for Good Indoor Air Quality

Section Six examines many issues associated with school design that may affect indoor air quality. This section discusses the role of the design team, the need for a pollutant source control plan, the status of codes and standards related to indoor air quality, assessing budget and schedule impacts, site and facility planning, HVAC design recommendations, and ways to reduce emissions and air quality impacts of building materials, interior finishes and furnishings.

Section Seven: Constructing Schools for Good Indoor Air Quality	*Section Seven* discusses indoor air quality issues and their relationship to construction monitoring, school building commissioning, and initial occupancy of buildings. This section also offers recommendations for maintaining good indoor air quality in occupied schools while remodeling or renovation is in progress. Painting, carpeting, and roofing projects are addressed specifically, since they are routinely undertaken in building improvement projects.
Section Eight: Operating and Maintaining HVAC Systems for Good Indoor Air Quality	*Section Eight* describes the importance of properly operating and maintaining HVAC systems. Documentation needs for HVAC systems are discussed, and maintenance standards and requirements for HVAC systems are outlined.
Section Nine: Controlling Contaminant Sources in and around Schools	*Section Nine* discusses several issues of general concern at schools which can affect indoor air quality. Tobacco smoking, storage and use of cleaning and maintenance materials, dust control, prevention of microbial growth following spills or leaks, pest control, and asbestos and radon management are addressed in this section.
Section Ten: Controlling Contaminant Sources in Classrooms, Offices, and Special Use Areas	*Section Ten* describes design, construction, and operational practices which are important in maintaining good indoor air quality in classrooms and general offices, as well as special use areas within school buildings. Special use areas addressed in this section include staff work rooms and printing rooms, food handling areas, locker rooms, science laboratories, art and theater rooms, vocational arts areas, and swimming pools.
Section Eleven: Indoor Air Quality Planning and Management	Special measures to site, design, and construct or renovate schools as recommended in Sections Six through Ten of this Manual will reduce the likelihood that indoor air quality problems will arise. However, once buildings are occupied, it is important to assign responsibilities and carry out an active program to maintain good indoor air quality. As described in *Section Eleven*, this program includes the designation of an IAQ coordinator, development and use of an indoor air quality plan, training, education, and ongoing communication with school staff, students, parents, and other interested groups regarding indoor air quality issues. In addition, Section Eleven outlines the basic steps necessary to handle indoor air quality problems reported by staff or students.

Section Twelve: Other Resources

There are numerous federal, state, local, private, and non-profit organizations involved in indoor air quality issues. These organizations may provide funding or technical assistance, conduct research, supply publications, serve in a regulatory capacity, or represent special interest groups. *Section Twelve* provides names, addresses, and phone numbers for many of these organizations.

Appendices

Two documents referenced in the Manual are included as appendices:

- *Appendix A: Washington State Department of Health School Indoor Air Quality Survey*
- *Appendix B: HVAC Checklist*

Section Two: Why Manage School Indoor Air Quality?

Introduction

Over the last two decades, much attention has been focused on improving the quality of our outdoor air. Within the last ten to fifteen years, considerable attention has also been directed toward the problems of indoor air quality. During this period it has become increasingly clear that exposure to contaminated indoor air may not only be unpleasant, but in some instances may have serious adverse health effects.

Levels of specific contaminants in indoor air may be significantly higher than levels found outdoors. For instance, concentrations of contaminants such as *formaldehyde, other volatile organic compounds (VOCs), pesticides, radon, molds and bacteria, and byproducts of combustion such as solid particles, carbon monoxide and nitrogen oxides* may be considerably higher indoors than outdoors.[1]

Of course, there are many factors which influence indoor air pollution levels. These factors include the activities of building occupants (including maintenance activities), the presence of contaminant sources such as building materials, furnishings and equipment, the levels of contamination outdoors, the season, indoor humidity and temperature, and ventilation rates.

Not only are we potentially exposed to a *greater level* of contamination indoors than outdoors, most of us are exposed to indoor air for a *longer period* of time: on average, we spend over 90 percent of our time indoors.[1]

Poor Indoor Air Quality in Schools: The Consequences

This section of the Best Management Practices Manual provides an overview of the consequences of poor indoor air quality in schools, and discusses the extent to which indoor air quality problems may affect Washington State schools.

Health Symptoms and Problems

The Most Common Symptoms Resulting from Poor Indoor Air Quality

The health effects associated with indoor air quality problems are often non-specific symptoms rather than clearly defined illnesses. The symptoms most commonly attributed to indoor air quality problems include:

- headache, fatigue, and shortness of breath
- sinus congestion, coughing, and sneezing
- eye, nose, throat, and skin irritation
- dizziness and nausea

Mucous membrane irritation and respiratory symptoms are the most common symptoms experienced or reported in school buildings with indoor air quality problems. Other physiologic systems can also be affected by exposure to indoor air contaminants. Irritation, pulmonary, cardiovascular, and nervous system effects are highlighted briefly below.[2,3] (Section Three of the Manual provides additional information on indoor air pollutant sources and comfort and health effects--See Table 3-1):

- Indoor air pollutants may *irritate* the skin, eyes, nose and throat, upper airways, cranial nerves, and create dry mucous membranes, erythema (redness or inflammation of the skin), headache, and abnormal taste. Formaldehyde and other VOCs, combustion products, and particulates are examples of pollutants which may cause these symptoms.

- *Pulmonary* effects may include rapid breathing, increased infection rate, exacerbation of asthma, allergies, and flu-like symptoms. Combustion products, formaldehyde and other VOCs, and particulates can produce pulmonary effects. Some individuals may also be susceptible to certain biological air contaminants, resulting in hypersensitivity diseases including hypersensitivity pneumonitis and humidifier fever. Legionnaire's disease can occur from aerosolization of Legionella bacteria from HVAC cooling towers, humidifiers, and evaporative condensers.

Cardiovascular effects may include fatigue and dizziness. Exposure to combustion products, VOCs, and particulates are most commonly associated with these symptoms. Elevated carbon monoxide levels can aggravate existing cardiovascular disease, and cause chest pain and heart damage.

- *Nervous system* effects may include headache, fatigue, malaise with nausea, and in certain circumstances, lack of coordination, impaired judgment, and blurred vision. Combustion products, formaldehyde and other VOCs, and biological pollutants are most commonly associated with nervous system effects.

Cancer and reproductive effects have also been associated with exposure to indoor air contaminants. Such effects tend to have long periods of induction with effects not seen until years after exposure has taken place. Agents which are associated with these effects, including heavy metals and some solvents, are routinely used in certain fields of instruction such as science, vocational arts, and art.

Staff and students must be trained to take precautions in storing and handling toxic materials used in school curricula, and to use less toxic products where possible. In addition, the proper design and operation of instructional facilities and equipment, including exhaust systems, is essential to avoid exposure either to classroom participants or other building occupants. Staff or students who are pregnant must be especially protected from exposure since developing fetuses may be particularly susceptible to environmental toxins.

State and local health officials or other qualified occupational health and safety professionals may be consulted to answer questions concerning the health risks associated with exposure to indoor air contaminants (or hazardous materials), and to identify ways to minimize or reduce such risks.

People with allergies, asthma, or damaged immune systems may also be more susceptible to certain indoor contaminants. This is noteworthy, since there has been a significant increase in the prevalence of asthma in children over the past decade. Nevertheless, there are some people who appear to be more susceptible to indoor air contaminants who have no underlying health condition.

Other Consequences of Poor Indoor Air Quality

Increased Spread of Infectious Diseases

Biological agents in indoor air can cause disease. Diseases may include infections, hypersensitivity (where specific activation of the immune system causes disease), and toxicoses (where biologically produced chemical toxins cause direct toxic effects). Infectious diseases which can be spread through indoor air or personal contact include influenza, other respiratory viruses, tuberculosis, and measles. These diseases are more likely to be spread in indoor environments that are overcrowded and inadequately ventilated.[2,3]

Sensitivity of Children to Indoor Contaminants

Children may be more likely to be adversely affected by indoor air pollution than adults. Children breathe a greater volume of air relative to their body weight than adults, and this may lead to a greater burden of pollutants on their bodies.[4]

Although children may be affected to a greater degree than adults, the younger age groups in particular are less likely to comprehend and clearly communicate their discomfort or adverse health effects than adults. However, children may show signs of discomfort, including restlessness, sleepiness, or other symptoms as a result of poor indoor air quality.[5]

Multiple Chemical Sensitivity Syndrome

Multiple chemical sensitivity syndrome (MCSS) is a diagnosis for which a single cause has not been identified. Many of the symptoms associated with exposure to indoor air pollutants are experienced by individuals who are considered to be multiple chemical sensitive. The most frequent symptoms include headache and fatigue. Considerable debate exists within the medical and scientific communities as to whether MCSS exists as a true clinical entity. Understanding of and agreement upon the nature, causes, diagnosis, and treatment of MCSS are even more limited.

Generally MCSS is thought to be acquired by certain individuals when they are exposed to environmental contaminants (which may include indoor air contaminants) and become sensitized. People may become sensitized through a single high-level exposure, or a long-term low-level exposure. Once sensitized, these individuals may experience severe illness symptoms when exposed to the same chemicals, or unrelated chemical substances. Symptoms may occur with very low levels of chemical exposure--levels which do not cause symptoms in most of the general population.[6,7]

Although there is little agreement within the medical community concerning the nature, causes, and treatment of MCSS, practices to prevent indoor air contamination may help reduce the incidence of MCSS (if it is determined to be a clinical entity) and should provide a more comfortable environment for those persons thought to have MCSS.

Reduced Productivity in Students, Teachers, and Staff

Students, teachers, and other school staff need a healthy and comfortable environment in which to function. Problems associated with indoor air quality may lead to discomfort or illness, which in turn may lead to reduced productivity and academic performance, and increased absenteeism.

Strained Relationships among Parents, School Administration, and Staff

Indoor air quality problems can create tension and strain relationships among parents, school administrators, teachers, and other school staff. Parents expect a healthy school environment for their children. If indoor air quality problems develop, parents may blame the school district for failure to take proper precautions to ensure a safe school environment. Relationships may deteriorate if indoor air quality problems are not promptly and effectively addressed, or if there is poor communication among administrators, staff, and parents.

Potential for School Room or Building Closures and Relocation of Occupants

Resolving indoor air quality problems is often a difficult task, and solutions may not be readily apparent or quickly implemented. To ensure the comfort and health of students and staff, it may be necessary to restrict access to school rooms, other areas of the school building, or close the entire building until investigations and corrective actions have been taken.

Closure of school rooms and buildings may have serious, adverse consequences for the district, students, parents, and staff. The consequences include disruption of learning, transportation, and child-care arrangements, and the potential for closure to permanently undermine the confidence of students, parents, and staff in the safety of the building and the indoor air quality management practices of the district.

Some students may have pre-existing conditions that make them more susceptible to environmental toxins, including indoor air contaminants. If such conditions are medically-documented, the school district may need to relocate these individuals, or provide alternative accommodation to assure a healthy learning environment.

Deterioration of Buildings and Equipment

Failure to properly maintain buildings or equipment may contribute to poor indoor air quality. This may not only create discomfort and adverse health effects in building occupants, but may lead to equipment malfunctions, and further deterioration of buildings, equipment, and furnishings. Warranties on equipment and furnishings may be void from improper care. Once problems arise, the costs for additional cleaning, repair, replacement or maintenance of the building, equipment and furnishings may be substantially higher than the cost savings from deferred maintenance.

Increased Liability and Risk

Problems related to poor indoor air quality may lead to legal claims and expenses, including judgments and settlements. Industrial insurance claims may be filed by teachers and other staff members experiencing illness from contaminated indoor air. Payroll costs may escalate due to increased absenteeism. As noted above, there also may be unexpected costs for repair, replacement, and maintenance of structures, furnishings, and equipment. In addition, resolution of indoor air quality problems may be costly, depending upon the nature and extent of investigations and corrective actions required.

Special Considerations in Schools

Schools present special problems for managing indoor air quality. Students and teachers in classrooms are often working closer together than people in typical office buildings. Approximately four times as many people may occupy a given amount of floor space in a school classroom as an office.[4]

Schools also have a diversity of activities, and consequently have a wide range of potential air pollutant sources. These sources include cafeterias; art, science, and other classrooms; vocational education areas; pools; restrooms; and locker rooms.

Given these special circumstances and the sensitivity of children to environmental contaminants, it is important to prevent indoor air quality problems to the extent possible, and to effectively manage and resolve indoor air quality complaints and incidents which arise.

Indoor Air Quality in Washington State Schools

Goal: Encourage the Use of Sound, Cost-Effective Management Practices

It is the goal of the Office of the Superintendent of Public Instruction and the Department of Health to encourage the use of sound, cost-effective management practices to ensure good indoor air quality in public and private schools.

The Extent of Indoor Air Quality Problems in Washington Schools

There are approximately 1,860 public schools in Washington State, operating an estimated 5,000 school buildings. The number of school buildings *does not* include portable classrooms, which are not inventoried. Although exact figures are not available, the extent of indoor air quality problems in Washington State schools can be estimated.

A recent survey conducted by the Washington State Department of Health revealed that 33 of 132 responding schools which had been constructed or remodeled within the last five years had experienced indoor air quality problems. The average reported cost to address these indoor air quality problems was $134,750. Since this survey was voluntary, most schools chose not to respond. A copy of the survey form and summary of the survey results are presented in Appendix A.

The Washington State Department of Labor & Industries has estimated that approximately twenty percent of all on-site consultation visits requested by employers during the late 1980s and early 1990s were related to indoor air quality problems. A significant number of these on-site consultation visits were in schools.

During the last five years, the Department of Labor & Industries was able to document fifty-two indoor air quality field consultations in schools. Due to resource limitations, two years ago the agency's consultation section stopped routine on-site investigation of indoor air quality problems. An informational handout dealing with general indoor air quality concerns is mailed out by the agency upon request.

In addition to consultation visits, the Department of Labor & Industries' compliance section has responded to indoor air quality problems at schools that are generated as a result of employee complaints.

The U. S. Occupational Safety and Health Administration (OSHA) has estimated that *twenty to thirty* percent of non-industrial buildings have problems with indoor air quality.[2] This estimate is not necessarily representative of the magnitude of school indoor air quality problems in Washington State. On the other hand, if the figures are reasonably representative, it may be concluded that hundreds of school buildings in the state experience indoor air quality problems, not including problems which may exist in portable classrooms. Potentially thousands of students, teachers, and other school staff members are exposed to poor indoor air quality.

What is Needed to Prevent and Manage School Indoor Air Quality Problems

Many indoor air quality problems can be prevented. The costs of preventing indoor air quality problems are likely to be less than the costs of resolving problems after they develop. Good practices in siting, design, construction, and operation and maintenance of schools will help school districts avoid these problems.

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Section Three: Factors Influencing Indoor Air Quality

Introduction

Sources of Indoor Air Contaminants

Staff and student satisfaction, comfort, and health associated with the school building are related not only to indoor air quality, but to a number of other factors. The non-specific health symptoms described in Section Two may be caused by indoor air quality or other environmental stressors such as improper lighting, noise, vibration, over-crowding, uncomfortable furniture, and job or classroom related psychosocial problems (such as stress).

This section will focus on the *sources* of indoor air contamination. Comfort and health effects for specific contaminants will be briefly described, and control measures for addressing these contaminants will be outlined. Sections Four through Eleven of the Manual describe in greater detail control measures for indoor air pollutants.

Indoor air may be contaminated by sources *outside* a building as well as from sources *inside* the building. Contaminants may consist of *particles and dust (including microbial debris), fibers, mists, biological particles, and gases or vapors.*

Following are examples of contaminant sources outside and inside buildings that may contribute to indoor air pollution.[1, 2]

Outside Sources of Contamination

Contaminated Outdoor Air

- pollen, dust, and fungal spores
- industrial pollutants
- emissions from residential heating units, such as wood smoke
- area-wide vehicle exhaust and emissions

Emissions from Nearby Sources

- exhaust from vehicles on roads, in parking lots, garages, or loading docks near school buildings
- odors from dumpsters or trash storage areas, or other areas with unsanitary debris near the building outdoor air intake

- emissions from nearby construction activities
- pesticides applied to crops in the school's vicinity
- livestock operations
- exhaust from the building itself or from neighboring buildings which is drawn back into the building through outdoor air intakes

Surface and Underground Sources

- radon
- leakage from underground fuel tanks
- contaminants from previous uses of the site (for example, buried or discharged solid or hazardous waste)
- pesticides

Moisture or Standing Water Promoting Microbial Growth

- rooftops after rainfall
- crawl spaces
- nearby wetlands
- stormwater treatment systems

Building Components and Furnishings

Locations that Produce or Collect Dust or Fibers

- textured surfaces such as carpeting, curtains, and other textiles
- open shelving
- office dividers
- baseboard heating units
- old or deteriorated furnishings
- materials containing loose asbestos

Unsanitary Conditions and Water Damage

- microbial growth on or in soiled or water-damaged carpets and furnishings
- microbial growth in areas of surface contamination
- standing water from clogged or poorly designed drains
- dry traps that allow the entry of sewer gas
- moisture damage from aquariums, or maintenance of indoor plants

Chemicals Released from Building Components or Furnishings

- pressed wood products
- glues, adhesives, sealants
- insulating materials
- flooring and wall coverings
- plastics
- electrical equipment

Building Equipment

The Heating, Ventilation, and Air Conditioning System

- dust or dirt in ductwork, filters, or other components
- microbial growth in drip pans, humidifiers, ductwork, coils
- improper use of biocides, sealants, or cleaning compounds
- improper venting of combustion products
- refrigerant leakage
- natural gas pipe leakage

Other Building Equipment

- emissions from office equipment (volatile organic compounds, ozone)
- emissions from supplies (solvents, toners, ammonia)
- emissions from shops, labs, cleaning processes
- emissions from elevator motors and other mechanical systems

Human Activities

Personal Activities

- body odors
- cosmetic odors
- coughing and sneezing
- smoking (note: smoking is banned on public school grounds)

Housekeeping Activities

- cleaning materials and procedures
- emissions from stored supplies or trash
- use of deodorizers and fragrances
- airborne dust or dirt (for example, circulated by sweeping and vacuuming)

Maintenance Activities

- microorganisms in mist from improperly-maintained cooling towers
- airborne dust or dirt
- odors and volatile organic compounds from paint, caulk, adhesives, and other products
- pesticides from pest control activities
- emissions from stored supplies

Other Sources

Spills, Leakage, Accidents

- spills of water or other liquids
- microbial growth due to flooding or leaks from roofs or pipes
- fire damage (soot, PCBs from electrical equipment, odors)

Special Use Areas within the Building

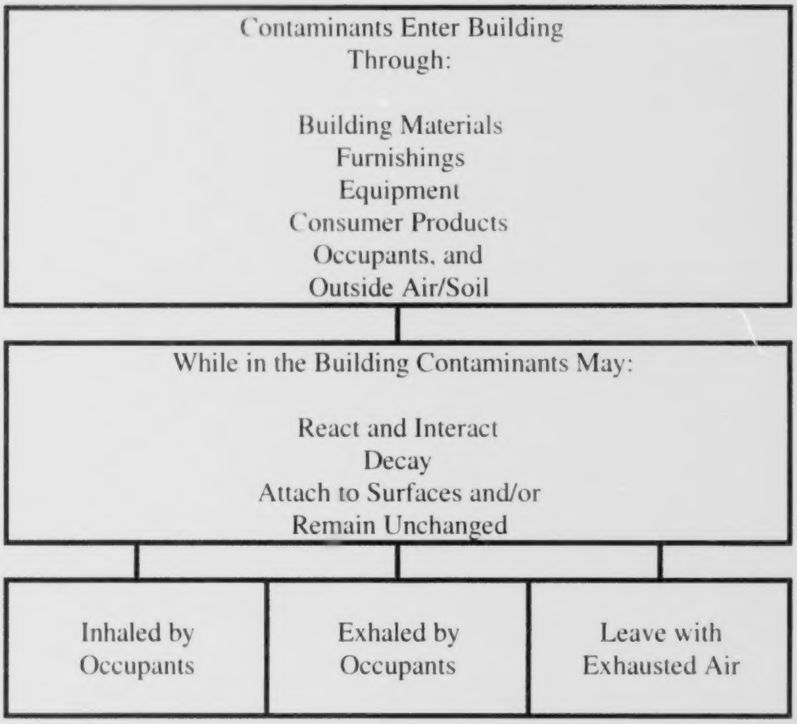
- science laboratories
- photo/printing rooms
- art rooms
- restrooms and locker rooms
- pools
- cafeterias and other food handling areas
- staff work rooms
- vocational arts areas

Redecorating, Remodeling, and Repair Activities

- emissions from new furnishings
- dust and fibers from demolition
- odors and volatile organic and inorganic compounds from paint, caulk, adhesives, and other products
- microbial debris released from demolition or remodeling activities

The generation and flow of indoor air pollutants may be depicted graphically. Figure 3-1 provides a simplified view of indoor air pollutant sources, and the fate of these pollutants in the building environment.[3]

Figure 3-1: Indoor Air Pollutant Flow


Contaminants Enter Building Through:
Building Materials
Furnishings
Equipment
Consumer Products
Occupants, and
Outside Air/Soil
While in the Building Contaminants May:
React and Interact
Decay
Attach to Surfaces and/or
Remain Unchanged
Inhaled by Occupants
Exhaled by Occupants
Leave with Exhausted Air

Typical Indoor Air Pollutants, Sources, Comfort and Health Effects

Various pollutants or contaminants are released from the *sources* listed above. Table 3-1 lists the typical indoor air pollutants, identifies their potential sources, describes comfort and health effects, and suggests control measures to reduce or eliminate the pollutants.[3,4,5,6,7]

Sections Four through Eleven of this Manual provide many recommendations to control and prevent problems from these and other indoor air pollutants. For additional information on indoor air pollution sources, health effects, and regulations or guidelines for control, the reader should consult the reference list at the end of this Section, and review *Section Twelve: Other Resources*.

Table 3-1
Typical Indoor Air Pollutants: Description and Sources

Pollutant	Description	Sources
Asbestos	Asbestos is composed of small, natural mineral silicate fibers. Chrysotile is the most commonly used asbestos and represents about 95 percent of the asbestos used in buildings in the United States.	Widely used in insulation and other building materials manufactured before 1977. Examples include pipe and furnace insulation, vinyl floor tiles and sheet flooring, patching compounds, textured paints, roofing materials, wall and ceiling insulation.
Formaldehyde	Formaldehyde is a colorless, water soluble gas. Due to its wide use, it is frequently considered separately from other volatile organic compounds (VOCs).	Materials containing formaldehyde are widely used in buildings, furnishings, and consumer products. Urea-formaldehyde resins are used in the manufacture of plywood, particle board, fiberboard, and textiles. Other potential sources include furniture, shelving partitions, ceiling tiles, wall coverings, and carpet backing. The walls of some buildings have been insulated with urea-formaldehyde foam insulation (UFFI). Tobacco smoke and incomplete combustion of cooking and heating fuels are secondary sources.
Other Volatile Organic Compounds	Volatile Organic Compounds (VOCs) are compounds that vaporize (become a gas) at room temperature. There are hundreds of VOCs found in the indoor air, sometimes in concentrations suspected of being harmful.	VOCs evaporate from many housekeeping and maintenance products, building materials, furnishings and equipment, and from human metabolism. Examples include: *acetone, alcohols:* byproducts of human metabolism, cleaners, personal care products. *ammonia:* cleaners, diazo copiers. *aromatic hydrocarbons:* combustion processes, pesticides, paints, solvents. *benzene:* combustion processes, gasoline, solvents. *chlorinated hydrocarbons:* PCBs, wood preservatives, solvents. *styrene:* carpet systems. *phenols:* equipment, furnishings. *toluene:* adhesives, gasoline, paints, solvents. *4-phenyl cyclohexane (4-PC):* carpet systems.

Table 3-1
Typical Indoor Air Pollutants: Comfort and Health Effects, and Control Measures

Pollutant	Comfort and Health Effects	Control Measures
Asbestos	No acute health or comfort effects due to asbestos are known. Fibers deposited in the lung are the only known cause of mesothelioma, a rare cancer of the chest and abdominal lining. Asbestos is also associated with cancer of the esophagus, stomach, colon, and other organs. It can also cause asbestosis, a non-cancerous chronic and debilitating lung disease found in high-level industrial exposures.	The methods of asbestos abatement include repair, removal, enclosure, and encapsulation. Removal has often been the abatement method of choice, although removal is not necessarily the most cost-effective method to protect human health and the environment.
Formaldehyde	Formaldehyde has a pungent odor and is detected by many people at levels of about 0.1 parts per million (ppm). Besides the annoyance, at higher concentrations it can also cause eye, nose, and throat irritation, coughing, wheezing, fatigue, skin rashes, and in rare cases, serious allergic reactions. Formaldehyde has caused nasal cancer in laboratory animals, but chronic effects have not been established for human beings. Some people exhibit a high sensitivity to very small concentrations.	For problem UFFI cases, removal is indicated although the cost can be high. Even then, residual materials may remain in the structure and continue to off-gas. Increased temperature, humidity, and ventilation will accelerate off-gassing of formaldehyde from products. Therefore, ventilation may not be an effective means of control. Some manufacturers are producing products with lower off-gassing rates. Some surface treatments (such as nitrocellulose or water based polyurethane finishes) are being used to reduce off-gassing.
Other Volatile Organic Compounds	Several of these compounds have been identified individually as causing acute and chronic effects at high concentrations. At higher concentrations than are typically expected in school buildings, some VOCs have been linked to cancer in humans, and others are suspected of causing cancer. Anecdotal reports suggest that combinations of these compounds in low concentrations may be associated with sick building incidents. However, this phenomenon has not been confirmed through rigorous experimental or observational studies. Symptoms attributed to VOCs includeespiratory distress, sore throat, eye irritation, nausea, drowsiness, fatigue, headaches, and general malaise.	Selective purchasing and use of construction materials, furnishings, operational and maintenance materials can help reduce VOC emissions. Products should be stored in well-ventilated areas apart from occupied zones. Increased ventilation or direct exhaust can be used for activities that have high VOC emissions, such as painting. Scheduling the use of products to avoid occupant exposure to high levels of VOCs can also be useful.

Table 3-1
Typical Indoor Air Pollutants: Description and Sources

Pollutant	Description	Sources
Nitrogen Oxides	The two most prevalent oxides of nitrogen are nitrogen dioxide (NO_2) and nitric oxide (NO). Both are toxic gases with NO_2 being a highly reactive oxidant, and corrosive. NO gradually reacts with the oxygen in the air to form NO_2.	The primary sources indoors are combustion processes, such as unvented combustion appliances, vented appliances with defective installations, welding, vehicle exhaust, and tobacco smoke. Combustion appliances include wood, gas, and coal stoves, unvented kerosene heaters, and fireplaces subject to backdraft.
Carbon Monoxide	Carbon monoxide (CO) is a colorless, odorless, and tasteless gas. It results from incomplete oxidation of carbon in combustion.	Incomplete oxidation during combustion in gas ranges, unvented heaters, leaky wood and coal stoves, and tobacco smoke may cause high concentrations of CO in indoor air. Worn or poorly adjusted and maintained combustion devices can be significant sources. Automobile, bus, or truck exhaust entering buildings from attached garages, nearby roadways or parking areas can also be a source of CO.
Carbon Dioxide	Carbon dioxide (CO_2) is a colorless, odorless, and tasteless gas. It is a product of completed carbon combustion.	All combustion processes and human metabolic processes are CO_2 sources. Concentrations of CO_2 from people are always present in occupied buildings.
Airborne Biological Pollutants	Biological materials, bacteria, viruses, fungi (molds and yeasts), pollen, dander, and insect parts (cockroaches and dust mites) are present nearly everywhere in indoor environments. These particulates range from less than one to several microns in size. When airborne, they are usually attached to dust particles of various sizes so that all sizes of airborne particles may include them.	People, plants, pets, and insects may serve as sources or carry biological agents into a building. Drapery, bedding, carpeting, and other places where dust collects can harbor them. Cooling towers, dirty air conditioning equipment, humidifiers, condensate drains, and ductwork can incubate bacteria and molds. Other sources include wet or damp building materials and furnishings, including insulation, carpet, ceiling tiles, wall coverings, and furniture.

Table 3-1
Typical Indoor Air Pollutants: Comfort and Health Effects, and Control Measures

Pollutant	Comfort and Health Effects	Control Measures
Nitrogen Oxides	Oxides of nitrogen have no sensory effect in low concentrations. Acute effects of lung dysfunction have been reported at higher concentrations. Oxides of nitrogen produce delayed short-term effects on airway activity. Persons at special risk are those with chronic bronchitis, emphysema, asthma, and children under two years old. Long-term or chronic effects are not well established.	Venting the sources of nitrogen dioxide to the outdoors is the most practical measure for existing conditions. This includes proper installation, operation and maintenance of all combustion appliances, and prevention of vehicle exhaust entry into buildings.
Carbon Monoxide	Acute or short-term effects of carbon monoxide (CO) exposure are due to the formation of carboxyhemoglobin in the blood, which inhibits oxygen intake. At moderate concentrations, symptoms may mimic influenza and include fatigue, headache, dizziness, nausea, and vomiting. Other symptoms include impaired judgment and impaired vision. At higher concentrations, CO exposure is fatal.	It is most important to be sure combustion equipment is maintained and properly adjusted. Vehicular use should be carefully managed adjacent to buildings and in vocational programs to avoid entry of exhaust into buildings. Additional ventilation can be used as a temporary measure when high levels of CO are expected for short periods of time.
Carbon Dioxide	Carbon dioxide (CO_2) is a simple asphyxiant. At concentrations over 1.5 percent, breathing becomes more difficult. Above 3 percent, CO_2 causes nausea, headaches, and dizziness, and above 6 to 8 percent stupor and death can result. At lower concentrations (0.1 percent), building occupants may experience headaches, fatigue, or eye and respiratory tract irritation. However, at these low concentrations, the buildup of CO_2 indicates inadequate ventilation, with the symptoms resulting from the concentration of other indoor air contaminants.	Ventilation with fresh air is used to control carbon dioxide levels.
Airborne Biological Pollutants	Tuberculosis, measles, staphylococcus infections and influenza are known to be transmitted by air, as is Legionnaires disease. Pollens and molds can cause allergic reactions for a significant portion of the population. Common symptoms include sneezing, watery	Good housekeeping and maintenance of HVAC equipment are very important. Adequate ventilation and good air distribution also help. Higher efficiency air filters remove viable particles along with other particles. Any water-

	eyes, coughing, shortness of breath, dizziness, lethargy, fever, and digestive problems.	damaged building materials or furnishings should be promptly cleaned, dried, or replaced. Maintain relative humidity between 40 to 60 percent. Cooling tower treatment procedures exist to reduce levels of Legionella and other organisms.

Table 3-1
Typical Indoor Air Pollutants:
Description and Sources

Pollutant	Description	Sources
Body Fluids	Blood and body fluid spills such as vomit, urine, and saliva.	Usually children but may be any building occupant. Spills may result from illness, personal injury, or chronic conditions.
Heavy Metals	Heavy metals of concern include lead dust and mercury vapor.	Lead sources include lead based paint, exterior dust and soil, lead-containing foodware, and art and craft materials, such as paints, glazes, stained glass, and solder. Mercury sources include mercury compounds (such as phenylmercuric acetate) used as preservatives in latex paint manufactured before August 1990. In addition, mercury may also be released from laboratory spills, such as the breakage of thermometers.
Radon	Radon is a radioactive gas, the first decay product of Radium-226. It decays into solid alpha emitters which can be both inhaled directly or attach to dust particles that are inhaled. The unit of measure for radon is picocuries per liter (pCi/l).	Radon is present nearly everywhere in the earth's crust in widely varying concentrations. Radon may enter a building through the water system or through off-gassing of building materials. However, the earth below buildings is the principal source of indoor radon. Radon penetrates cracks and drain openings in foundations, and enters basements and crawl spaces.

Table 3-1
Typical Indoor Air Pollutants: Comfort and Health Effects, and Control Measures

Pollutant	Comfort and Health Effects	Control Measures
Body Fluids	May cause discomfort and health effects in other building occupants.	Body fluid spills should be immediately cleaned up and disposed. A spill kit should be maintained and used as necessary. The kit should include a bucket, disinfectant, body fluid absorbent material, disposable gloves, paper towels, sealable plastic bags, plastic bandages, gauze, and a brush. School personnel should see that the kit is maintained with these components.
Heavy Metals	Significant lead exposure in infants and small children may lead to irritability, abdominal pain, seizures, loss of consciousness, chronic learning deficits, hyperactivity and reduced attention span. In adults, symptoms may include fatigue, weakness, headache, hearing loss, tremor, lack of coordination, gastrointestinal discomfort, constipation, anorexia, and nausea. With high doses or prolonged exposure, mercury poisoning symptoms may include muscle cramps or tremors, headache, tachycardia (abnormally high heart rate), intermittent fever, acrodynia (symptoms including leg cramps, irritability, peeling skin, and painful red fingers), personality change, and neurological dysfunction.	Wet mop and wipe furniture to control lead dust. Have professionals remove or encapsulate lead containing paint, following evaluation of old painted surfaces. Avoid use of old latex paints containing mercury. Mercury spills may be handled through the use of commercial cleanup kits, HEPA vacuums (not ordinary vacuums), flowers of sulfur, or dental amalgam.
Radon	No sensory perception or immediate health effects are known. The chronic effect is lung cancer or other lung dysfunction due to the retention of radon decay products in the lung. These chronic effects are among the best known of all indoor air pollutants, as the result of studies on uranium miners. It is speculated that non-occupational radon exposure in the U.S. may cause between 2,000 and 20,000 additional cancer deaths per year.	Sealing of foundations to prevent entry has been demonstrated to be effective, although the long term reliability of sealing is unknown. Specific ventilation of basement areas and crawl spaces has also been shown to be effective. Increased ventilation with outdoor air will lower radon levels for a given building. However, radon levels do not correlate well with ventilation rates among different buildings; i.e., buildings with low ventilation rates will not necessarily have high indoor radon levels, and vice-versa. In new construction, radon entry may be controlled by pouring slabs with as few joints as possible, using wire reinforcement in slabs and walls to minimize cracking, using caulking to seal seams and perimeters, and using sub-slab ventilation techniques.

Pollutant Sources, HVAC Systems, Pathways, and Occupants[1,4]

The indoor environment of any building is a result of the interactions among the *site, climate, building structure and mechanical systems, construction techniques, contaminant sources*, and *building occupants*.

An indoor air quality problem may exist when there are *sources* of pollution or discomfort indoors, outdoors, or within the mechanical ventilation system. These sources are connected to building occupants through a *pathway*, with a *driving force* to move pollutants along the pathway. As an example, many of the sources of indoor air pollution described in this section of the Manual may be removed or distributed by the HVAC system, which serves as a pathway and driving force to reach building occupants.

Purpose and Features of the HVAC System

HVAC Systems[1,4]

The HVAC system includes all heating, ventilation, and cooling equipment serving a school: boilers or furnaces, chillers, cooling towers, air handling units, exhaust fans, ductwork, and filters. A properly designed and operating HVAC system will:

- control temperature and relative humidity to provide thermal comfort

- distribute sufficient amounts of outdoor air to meet ventilation needs of school occupants, and

- isolate and remove odors and contaminants through pressure control, filtration, and exhaust fans.

In the design of new schools or remodeling of older schools, these functions must be addressed. Older schools may not have an HVAC system which adequately serves these functions. In addition, improper operation and maintenance at any school, new or old, may prevent the HVAC system from properly doing its job.

The features of the HVAC system in a given building will depend upon several factors. These include:

- age of the system and design climate

- building and mechanical codes in effect at the time of the design
- budget that was available for the project
- designers'and school districts'individual preferences, and
- subsequent modifications.

Temperature Variations and Comfort[1,4]

Thermal comfort and ventilation needs are met by supplying *conditioned* air, which is a mixture of outdoor and recirculated air that has been filtered, heated or cooled, and sometimes humidified or dehumidified. A number of variables interact to determine whether people are comfortable with the temperature and relative humidity of the indoor air. The amount of clothing, activity level, age, and physiology of people in schools vary widely, so the thermal requirements for comfort vary among individuals. The American Society of Heating, Refrigerating and Air-Conditioning Engineers, Inc. (ASHRAE) Standard 55-1992 describes the temperature and humidity ranges that are comfortable for most people engaged in non-strenuous activities. Temperature is discussed further on page 6-20 of this Manual.

Uniformity of temperature is important to comfort. Rooms that share a common heating and cooling system controlled by a single thermostat may be at different temperatures. Temperature stratification is a common problem caused by a lack of mixing, when light, warm air rises, and heavier, cooler air sinks. If air is not properly mixed by the ventilation system, the temperature near the ceiling can be several degrees warmer or cooler than near the floor, where young children spend much of their time. Even if air is properly mixed, uninsulated floors over unheated spaces can create discomfort in some climate zones. Large fluctuations of indoor temperature can also occur when thermostats have a wide dead band (a temperature range in which neither heating or cooling takes place).

Radiant heat transfer may cause people located near very hot or very cold surfaces to be uncomfortable even though the thermostat setting and the measured air temperature are within the comfort range. Schools with large window areas sometimes have problems of discomfort due to radiant heat gains and losses, with the locations of complaints shifting during the day as the sun angle changes. Windows and poorly insulated walls can also produce a flow of air by convection, leading to complaints of draftiness.

Closing curtains reduces heating from direct sunlight and isolates building occupants from exposure to window surfaces which are often hotter or colder than the walls.

Large schools may have interior core spaces in which year-round cooling is required to compensate for heat generated by occupants, equipment, and lighting, while perimeter rooms may require heating or cooling depending on outdoor conditions.

The Effects of Humidity on Comfort Levels[1,4]

Humidity is a factor in thermal comfort. Raising relative humidity reduces a person's ability to lose heat through perspiration and evaporation, so that the effect is similar to raising the temperature. Humidity extremes can also create indoor air quality problems. Excessively high or low relative humidity can produce discomfort. High relative humidity (over 60 percent) can promote the growth of mold and mildew, while low relative humidity (below 30 percent) can accelerate the release of fungal spores into the air. Low humidity has been associated with irritation of the mucous membranes of the eyes and upper respiratory system.

Ventilation to Meet Occupant Needs[1,4]

All schools need *ventilation*, which is the process of supplying outdoor air to the occupied areas within the school. As outdoor air is drawn into the school, indoor air is exhausted by fans or allowed to escape through openings, thus removing indoor air pollutants. Exhaust is also taken directly from special use areas that produce air pollutants such as restrooms, kitchens, shops, and science materials storage closets and fume hoods.

Modern schools use mechanical ventilation systems to introduce outdoor air during occupied periods, and exhaust fans to remove odors and contaminants from special use areas. Older schools may have relied more upon natural ventilation to bring in fresh air. In naturally ventilated buildings, unacceptable indoor air quality is particularly likely when occupants keep the windows closed because of extreme hot or cold outdoor temperatures. Even when windows and doors are open, under-ventilation is likely when air movement forces are weakest, such as when there is little wind, or in multi-story buildings, when there is little temperature difference between the inside and outside of the building.
The amount of outdoor air considered adequate for proper

ventilation has varied substantially over the last several years. Because updating building codes often takes several years, the building code that was in force when the school HVAC system was designed may well have required a lower amount of ventilation than what is currently considered adequate. As a result, when these buildings are scheduled for major remodeling, many of them will need to have their HVAC systems upgraded.

ASHRAE ventilation standards are used as the basis for most building ventilation codes, including the Washington State Ventilation and Indoor Air Quality Code, Chapter 51-13 Washington Administrative Code (WAC). Generally for classrooms, libraries, music rooms, auditoriums, and kitchens, the ASHRAE recommended standard is *15 cubic feet per minute of outdoor air ventilation per occupant*, while office space and conference rooms should have *20 cubic feet per minute per occupant*. These recommendations may vary depending upon special conditions and occupancy of the room (number of people per 1000 square feet). Air flow requirements are discussed in detail in Section Six of the Manual, page 6-12.

Air Flow Patterns in Buildings[1,4]

Pollutant Pathways and Driving Forces

Air flow patterns in buildings result from the combined action of mechanical ventilation systems, human activity, and natural forces. Differences in air pressure created by these forces move airborne pollutants from areas of higher pressure to areas of lower pressure through any available opening.

The HVAC system is generally the predominant pathway and driving force for air movement in buildings. However, all of a building's components (walls, ceilings, floors, doors, windows, HVAC equipment, and occupants) interact to affect how air movement distributes pollutants within a building.

For example, as air moves from supply outlets to return inlets, it is diverted or obstructed by partitions, walls, and furnishings, and redirected by openings that provide pathways for air movement. On a localized basis, the movements of people have a major impact on the movement of pollutants. Some of the pathways change as doors and windows open and close. It is useful to think of the entire building as part of the air distribution system.

Air movement can produce many patterns of pollutant distribution, including:

- local air movement in a room containing a pollutant source will affect how the pollutant is distributed within the room
- air movement will transport pollutants into adjacent rooms or spaces that are under lower pressure
- pollutants may be moved into other spaces through HVAC system ducts
- pollutants may be moved from lower to upper levels in multi-story schools, and
- air and pollutants can move into the building through either infiltration of outdoor air or re-entry of exhaust air.

Natural forces exert an important influence on air movement between a school's interior and exterior. Both the *stack effect* and *wind effect* can overpower a building's HVAC system and disrupt air circulation and ventilation, especially if the school envelope (walls, ceilings, windows, doors) is leaky.

Stack Effect

Stack effect is the pressure-driven airflow produced by convection, the tendency of warm air to rise. The stack effect exists whenever there is an indoor-outdoor temperature difference, and the effect becomes stronger as the temperature difference increases. Multi-story schools are more affected than single-story schools. As heated air escapes from upper levels, indoor air moves from lower to upper levels, and outdoor air is drawn into the lower levels to replace the air that has escaped. Stack effect can transport contaminants between floors by way of stairwells, elevator shafts, utility chases, and other openings.

Wind Effects

Wind effects are transient, creating local areas of high pressure (on the windward side) and low pressure (on the leeward side) of buildings. Depending on the leakage openings in the building exterior, wind can affect the pressure relationships within and between rooms. Entry of outdoor air contaminants may be intermittent or variable, occurring only when the wind blows from the direction of the pollutant source.

Most public and commercial buildings are designed to be positively pressurized, so that unconditioned air cannot enter through openings in the building envelope causing discomfort or air quality problems. The interaction between pollutant pathways and intermittent or variable driving forces can lead to a single source causing indoor air quality complaints in an area of the school that is distant from the pollutant source.

Occupants Particularly Susceptible to Indoor Air Contaminants[1,4]

Building occupants include staff, students, and other people who spend extended time periods in the school. Some occupants may be particularly susceptible to effects of indoor air contaminants:

- allergic or asthmatic individuals
- people with respiratory disease
- people whose immune systems are suppressed due to chemotherapy, radiation therapy, disease, or other causes
- people on certain types of medication
- contact lens wearers

Some other groups are particularly vulnerable to exposures of certain pollutants or pollutant mixtures. For example:

- people with heart disease may be less tolerant to exposure to carbon monoxide (at lower levels) than healthy individuals
- children or adults who smoke, or who are exposed to environmental tobacco smoke (away from the school environment) are at higher risk of respiratory illness
- those with asthma or chronic lung disease exposed to significant levels of nitrogen dioxide (from combustion sources) are at higher risk of respiratory illness

Because of varying sensitivity among people, one individual may react to a particular indoor air quality problem while nearby occupants display no ill effects. Section Two of this Manual described the health symptoms and effects that may result from poor indoor air quality. It was also noted in the introduction to this section that there are other environmental stressors that may produce similar symptoms as those caused by poor indoor air quality.

Sick Building Syndrome

The term *sick building syndrome (SBS)* is used to describe cases in which building occupants experience short-term health and comfort effects that are often linked to the time they spend in the building, but disappear when they leave the building. The complaints may be localized in a particular room or zone or may be widespread throughout the building. Analysis of air samples often fails to detect high concentrations of specific contaminants, although in most cases, a physical basis that may contribute to the occurrence of SBS can be found, such as inadequate ventilation by the HVAC system.

Sick building syndrome symptoms include eye, nose, and throat irritation, dryness of mucous membranes and skin, nose bleeds, skin rash, mental fatigue, headache, cough, hoarseness, wheezing, nausea, and dizziness.[8]

Building-Related Illness

Building-related illness is a term referring to illness brought on by exposure to the building air, where symptoms of diagnosable illness are identified (for example, certain allergies or infections) and can be directly attributed to environmental agents in the indoor air. Legionnaire's disease and hypersensitivity pneumonitis are examples of building-related illness that can have serious or life-threatening consequences. Building related illness can develop as a result of poor building maintenance and uncontrolled sources of contaminants.[8]

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8. U.S. Department of Labor, Occupational Safety and Health Administration. 1994. Federal Register April 5, 1994, 29 CFR Parts 1910, 1915, 1926, and 1928. Indoor Air Quality; Proposed Rule. Washington, D.C. p.16005, 16006.

Section Four: Basic Strategies for Good Indoor Air Quality

Introduction

Most of the management practices recommended in this Manual fall into basic groups of actions or strategies for maintaining good indoor air quality. There are six *basic control methods* for reducing concentrations or avoiding elevated concentrations of indoor air contaminants. These six methods are:[1,2,3]

- source management
- local exhaust
- dilution ventilation
- exposure control
- air cleaning, and
- education.

In most cases, a combination of two or more of these strategies should be used to help ensure good indoor air quality.

Source Management

This method includes *source removal, source substitution*, and *source encapsulation*. *Source management* is the most effective method to control or avoid indoor air contamination when it can be practically and cost-effectively applied.

Source Management Methods:

1. *Source Removal*
2. *Source Substitution*
3. *Source Encapsulation*

The best prevention method is to avoid bringing unnecessary pollutant sources into the school building. Examples of *source removal* include prohibiting buses from idling near outdoor air intakes, and not placing trash or cleaning and maintenance supplies (which have the potential to release pollutants) in rooms where HVAC equipment is located.

Source substitution includes actions such as selecting a less toxic art material than one currently in use, or selection of a latex interior paint with low volatile organic compounds versus a solvent-based paint with higher volatile organic compounds.

Source encapsulation involves placing a barrier around the source so that it releases fewer pollutants into the indoor air. For instance, one approach to asbestos abatement involves encapsulation to prevent the release of asbestos fibers.

Local Exhaust

This method is quite effective in removing pollutants directly at their source before they can be dispersed into the indoor air, and involves exhausting the contaminated air outside. Examples include restroom and kitchen air exhausts, science lab fume hoods, art room kiln exhausts, housekeeping storage rooms, printing and duplicating rooms, and vocational arts rooms. Local exhaust (including the use of temporary exhaust) is also important when occupied school buildings are undergoing remodeling or repairs. Local exhaust can be used to help prevent staff and student exposure to contaminants during demolition and installation of new building materials.

Dilution Ventilation

This method uses outdoor air to dilute and replace contaminated indoor air. State and local building codes specify the amount of outdoor air that must be continuously supplied to an occupied area. For ventilation to be an effective control measure, other factors aside from the quantity of outdoor air must be considered. These factors include the quality of outdoor air, the effectiveness with which it reaches building occupants, the efficiency with which it reduces contaminant levels, and air pressure relationships between interior spaces and between inside the building and outdoors. Air pressure relationships help to prevent the distribution of contaminants from special use areas (such as kitchens and science rooms) into other parts of the building. *Ventilation requirements and recommendations are discussed further in Sections Six through Ten of this Manual.*

For activities such as painting, pesticide application, or responding to chemical spills, temporarily increasing ventilation can be useful in diluting the concentration of fumes in the air. However, ventilation may also distribute contaminants into other less-contaminated areas. It is advisable to consider the use of special, temporary local exhaust or local ventilation in such situations.

Exposure Control

Exposure Control Methods:

1. *Control Time of Use*
2. *Control Amount of Product Used*
3. *Control the Location of Use*

This method controls or limits the exposure of building occupants to contaminants by scheduling the *time* at which products producing emissions are used, controlling or limiting the *amount* of product used, and controlling the *location* of use.

An example of *time of use* exposure control would be to strip and wax floors on Friday after school is dismissed, so that the floor products have a chance to off-gas over the weekend, reducing the level of contaminants in the air when the school is occupied. (Note: the ventilation system must be operating during the period of contaminant off-gassing).

By controlling or restricting the *amount* of product used, fewer air contaminants will be present at the time the building is occupied.

Finally, *location* of use control simply means moving the contaminating source as far as possible from occupants, or relocating susceptible occupants. As an example, doors, trim, and other materials may be removed from a school room, stripped, painted or finished, and allowed to cure in a well-ventilated offsite location before reinstallation.

Exposure control methods may be used in conjunction with increased ventilation or local exhaust.

Air Cleaning

This method essentially involves the filtration of particles from the air as the air passes through the HVAC system. Filtration is important in reducing particles, including microbial agents, which can cause illness in building occupants. Gaseous contaminants can also be removed, but in most cases such removal is more difficult and costly. Removal of gaseous contaminants may be considered on a case-by-case basis, however.

Education

This method is a key component of the indoor air quality control strategy. If students, parents, teachers, custodians, and other staff are given information about the *sources and effects* of contamination and about the proper operation of the ventilation system, then they can work together to reduce their exposure and the exposure of others.

Education should lead to good building operation and maintenance practices, good housekeeping, and other preventive measures. Education should include a basic orientation on indoor air quality and this School Indoor Air Quality Best Management Practices Manual. Information should be provided at the school district and building levels, and should also be available to key policy makers, including local school board and site council members.

Provide an Orientation on Indoor Air Quality and the Best Management Practices for:

1. ***School District Staff***
2. ***School Building Staff***
3. ***Other Key Policy Makers***

Providing and maintaining good indoor air quality may require the expenditure of additional funds from the pre-design stage through the construction, building operation, and maintenance phases. These expenditures represent an investment, and are likely to reduce unanticipated expenditures to resolve indoor air quality problems in the future. The costs of providing good indoor air quality should be openly discussed by all involved parties, including school administrators, staff, parents, the school board, and site council.

Designating an Indoor Air Quality Coordinator

Purpose and Responsibilities of the Position

An indoor air quality coordinator should be assigned or hired to verify that practices to ensure good indoor air quality are carried out in all phases of school siting, design, construction, and ultimately in school operation. The IAQ coordinator selected for siting, design, construction, or renovation may not necessarily be the same person assigned as IAQ coordinator once the school is in operation.

In school siting, design, and construction, the IAQ coordinator should ensure that all IAQ objectives and issues defined for the school are considered through each phase. The IAQ coordinator should have good communication skills, have time available to devote to this function, and some technical expertise. The following tasks are among those which may be assigned to the IAQ coordinator during these phases of school development or renovation:

- assist in development and review of an indoor pollutant source control plan (discussed in Section Six of this Manual) to guide siting, design, and construction
- exchange information with state and local agencies
- obtain outside consulting assistance when necessary

- help to identify and communicate school district needs with the design/construction teams
- assist in the review of plans, activities, and work products for response to indoor air quality needs
- assure documentation of the rationale for decisions which vary from applicable best management practices (due to budget constraints, schedule restrictions, or other reasons), and
- help to ensure adequate documentation of indoor air quality activities and communication with school boards, site councils, administrators, other school district staff, and other interested and affected parties.

Who May be Assigned

The IAQ coordinator is serving as a resource person to the design team. Many of the tasks to be performed by the IAQ coordinator are administrative, and involve coordination of activities, communication, and documentation. Many of the technical tasks necessary to achieve good indoor air quality can be assigned to technical specialists, including architects and engineers, other professional service consultants and contractors. However, it would be valuable for the IAQ coordinator to have or acquire some training and/or job experience related to indoor air quality issues, the design, repair, or maintenance of air handling systems, and school construction and material selection.

The IAQ coordinator functions may be performed by administrative staff at the upper level administration in a school or school district. In conjunction with the school board, these positions are at a level with greater control of budget, staffing, and other resources than lower level positions. However, depending upon the needs and preferences of the school district, the IAQ coordinator functions may be performed by other personnel, such as technical staff with skills related to indoor air quality; personnel at the educational service district level; or by an independent consultant selected by the school district.[3]

References

1. Hansen, S. 1991. Managing Indoor Air Quality. The Fairmont Press. Lilburn, Georgia. p. 117-120.

2. Anne Arundel County Public Schools. 1989. Indoor Air Quality Management Program. Annapolis, Maryland. p. 15.

3. U.S. Environmental Protection Agency. 1995. Indoor Air Quality Tools for Schools. EPA 402-K-95-001. Washington, D.C. p. 5, 6, 15, 16.

Section Five: Siting Schools for Good Indoor Air Quality

Introduction

Site Selection Factors

School site selection is governed by many factors. These include cost, size and shape, location, safety, accessibility, availability of the site, and availability of public services and utilities. Among the factors related to site safety and environmental factors are those related to the presence of *environmental contaminants*, including potentially toxic and hazardous substances, air pollution, smoke, dust, and odors.[1]

The site evaluation team should consider whether a potential site is located on or near any potential source of odors, dust, or contaminants. Sources include: landfill areas; dump sites; industrial operations, such as chemical plants, wastewater treatment plants, fertilizer plants, chemical refineries, fuel storage facilities, or mining operations; abandoned fuel storage tanks; and agricultural areas such as stockyards, or areas in which pesticides and fertilizers have been heavily used.[1]

Section Five addresses the process of site evaluation. Activities may include conducting an environmental site assessment, assessing climate, examining ambient air quality and significant air emission sources, and assessing radon and other environmental factors.

Note: The practices specified or recommended in this Manual include some that are already required by code or law, and others that are recommendations which may help promote good indoor air quality in schools. It is the responsibility of each school district and other users of the Manual to comply with applicable codes and laws--including those related to building, plumbing, electrical and mechanical systems, fire protection, safety, energy use, and environmental protection. However, all users of the Manual, including school districts, should evaluate the discretionary recommendations presented in this Manual, and adopt or promote those which, in their judgment, are relevant and applicable to their circumstances, and feasible to implement. In the event that any recommendations offered in this Manual are in conflict with any applicable codes or laws, such codes or laws shall take precedence. Note that some of the recommended *activities are in addition to those customarily performed by outside consultants or in-house staff providing design or related professional services for school districts.*

Phase I Environmental Site Assessments

Review of Prior Uses of the Site and Adjacent Properties

It is important to review prior uses of the site and adjacent properties. Depending upon past site uses, hazardous substances may have been abandoned, discharged, or may have leaked on the property. Previous agricultural sites may have high concentrations of pesticides, herbicides, and fertilizers. Past commercial or industrial activities may have left improperly disposed solvents, adhesives, paints, oils and other products.

A good way to screen sites for environmental contaminants is to conduct a Phase I environmental site assessment (ESA). This assessment is designed to examine current and past uses of the property and adjoining properties, as well as activities within a reasonable distance (one-half mile to a mile) of the site which may affect environmental quality and public health at the site. ESAs typically involve review of state, federal, and local records, maps, files, and aerial photos. A site reconnaissance and interviews with past and present owners, occupants, and regulatory officials are also conducted.

Environmental site assessments can help to identify the existence of known or suspected solid or hazardous waste disposal sites, leaking or regulated underground storage tanks, and regulated hazardous waste generators and treatment or waste storage facilities. *ESAs and appropriate follow-up actions can help to identify potential problems prior to the decision to acquire school property.*

ESA Guidelines

Guidelines for conducting ESAs are often provided through lending institutions or environmental consulting firms. There are many environmental consulting firms with experience performing ESAs and related services that are available to assist school districts. A thorough guide for conducting environmental site assessments is available from the American Society for Testing and Materials (ASTM), entitled *Standard Practice for Environmental Site Assessments: Phase I Environmental Site Assessment Process*. This guidance document is available from ASTM at 1916 Race Street, Philadelphia, Pennsylvania 19103-1187. The organization's phone number is (215) 299-5400.

Climate Assessment

Climate--both local climate and the building site's microclimate may be considered as part of the site evaluation and design process. Climate assessment involves identifying prevailing winds and variations in wind patterns, and analysis of temperature and humidity patterns. This information is useful in designing the building envelope, and determining HVAC control strategies, equipment needs, equipment locations, and capacities.

Climate data are available from the National Oceanic and Atmospheric Administration (NOAA), the National Climate Data Center, Department of Commerce, airports, local air pollution control authorities, and academic and scientific institutions.

Although many factors influence building siting and design, wind data may help to identify the best locations for outdoor air intakes, exhausts, parking facilities, loading docks, and other features. During building operation, wind data can also be used to identify and respond to upwind contaminant sources which have the potential to affect indoor air quality.

Ambient Air Quality and Significant Sources Nearby

Quality of the Outside Air Supply

It is important to determine how clean the outdoor air is at a site, since this air ultimately will be used for ventilation. Such information may be used to determine whether or not a facility should be sited in a given location, or if sited, what air cleaning and filtration may be required.

Information should be gathered concerning ambient air quality from federal (U.S. Environmental Protection Agency (EPA)) and state or local agencies (Department of Ecology or the local air pollution control authority). Information available from EPA includes a national emissions report under the National Ambient Air Quality Standards (covering major metropolitan areas), and the Toxic Release Inventory which identify air emissions and other releases of toxic chemicals by manufacturing facilities. Pages 6-10 and 6-11 of this Manual discuss the National Ambient Air Quality Emission Standards in greater detail.

Of possible greater concern to outdoor air quality are nearby sites which may produce and release contaminants. Nearby sites may be of concern depending upon the types and quantities of contaminants produced. It may be useful to prepare a map of the areas

Table 5-1: Potential Sources of Ambient Air Contamination

Source Category	Facility Type
Commercial Facilities:	• Laundry and dry cleaning • Restaurants • Photo-processing shops and laboratories • Auto repair shops, gas stations, and body shops • Paint shops • Print shops
Manufacturing:	• Electronics manufacturing and assembly • Wood products, wood preservative treatment • Pulp and paper • Rendering • Refinishing • Petrochemical • Aluminum/metals • Food processing
Utilities:	• Electric power plants • Central steam plants • Sewage and water treatment
Agriculture:	• Greenhouses • Orchards • Open cropland • Livestock • Processing and packing plants
Traffic Areas:	• Highways • Parking lots • Loading areas

surrounding the site to show existing and potential contaminant sources. Information about nearby site activities and emissions may be obtained from a variety of sources, including the site owners and operators, and federal, state or local regulatory agencies. Some, but not necessarily all of these site activities may be identified through an ESA. Table 5-1 shows potential nearby site activities which may produce odors and other air contaminants of concern. The potential impact of nearby activities needs to be evaluated on a case-by-case basis.

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Assessment of Radon and other Environmental Factors

Radon

The presence of contaminants in the soil or groundwater can also indicate that the site may not be appropriate for purchase or use as a school, or specific measures may be needed to prevent or control contaminant entry.

For instance, groundwater and soil may contain radon, a naturally-occurring decay product of radium, and measures to control and prevent radon entry into buildings may be necessary. Radon may ultimately enter a building through cracks, utility openings, or gaps in the foundation or basement walls. Knowledge about the levels of radon at a site will influence the design of the structure (to prevent or minimize radon entry), and design and operation of the HVAC system (which may draw radon soil gases into a building, or conversely may remove them).

In Washington State, Spokane County has a *very high* radon potential. Other counties with a *high* radon potential are Asotin, Columbia, Ferry, Garfield, Okanogan, Pend Oreille, Skamania, Stevens, Walla Walla, and Whitman. Counties with variable radon potential are Adams, Benton, Clark, Douglas, Franklin, Grant, Klickitat, Lincoln, Wahkiakum, and Yakima. The remaining counties in Washington State are classified as having low radon potential.[2]

Detailed information on radon health effects, assessment, diagnosis, and mitigation measures which may be useful for schools are available in several publications. The reader is referred to the following sources: *School Radon Action Manual*, Second Edition, by the Washington State Department of Health; *Special Report--Radon in Washington*, by the Washington State Department of Health; *Reducing Radon in Schools: A Team Approach* by the U.S. Environmental Protection Agency; *Radon Reduction Techniques in Schools--Interim Technical Guidance*, by the U.S.
Environmental Protection Agency; and *Radon Measurement in Schools--Revised Edition*, by the U.S. Environmental Protection Agency. In addition, some counties have residential building codes governing radon protection which may be useful to review for school siting and design projects.

Other Factors

Other factors which indirectly affect the building include noise, and lighting. Excessive noise from traffic or other sources may be disruptive, and limit the use of windows for ventilation or temperature control. Glare from nearby buildings may affect the size, placement, and glazing of windows.

Documentation

All climate and site evaluation data should be documented. Climate data should include temperature and relative humidity; wind patterns, speed, and prevailing directions; ambient air quality information from federal, state, and local sources; and a plot of nearby known or potential air pollutant sources, with relevant supplemental information.

Specific data on the site should be compiled, including prior on-site and adjacent site history; an inventory of potential sources of contaminants; and soil and groundwater information. This information should be part of a larger documentation effort associated with school siting, and should be provided to the design team to assist in placing the building on the selected site. In addition to maintaining documentation at the school district, a copy of all site documentation must be made available (upon request) to the local health department in accordance with WAC 246-366-030.

References

1. California State Department of Education. 1989. School Site Selection and Approval Guide. Sacramento, California. p. 2, 3, 5, 10.

2. Washington Department of Health. 1994. Special Report--Radon in Washington. Olympia, Washington. p. 45, 46.

Section Six: Designing Schools for Good Indoor Air Quality

Introduction

Indoor air quality problems can result from poor decision-making at the design stage for school construction or renovation. Building shape and size, orientation, layout, location of pollutant generating activities, building materials, types of windows and doors, and general ventilation system design all can affect indoor air quality. It is important to consider these items early in the project and to include provisions in the contract documents which address indoor air quality issues. This is likely to reduce indoor air quality problems once the building is occupied.[1]

Section Six addresses key issues associated with indoor air quality as they relate to building design. The issues are organized into eight major headings:

- assembling the design team
- preparing an indoor pollutant source control plan
- complying with codes and standards
- assessing budget and schedule impacts
- site and facility planning
- HVAC design recommendations
- selection of materials, interior finishes, and furnishings, and
- design documentation

Note: The practices specified or recommended in this Manual include some that are already required by code or law, and others that are recommendations which may help promote good indoor air quality in schools. It is the responsibility of each school district and other users of the Manual to comply with applicable codes and laws--including those related to building, plumbing, electrical and mechanical systems, fire protection, safety, energy use, and environmental protection. However, all users of the Manual, including school districts, should evaluate the discretionary recommendations presented in this Manual, and adopt or promote those which, in their judgment, are relevant and applicable to their circumstances, and feasible to implement. In the event that any recommendations offered in this Manual are in *conflict with any applicable codes or laws, such codes or laws shall take precedence. Note that some of the recommended activities are in addition to those customarily performed by outside consultants or in-house staff providing design or related professional services for school districts.*

Assembling the Design Team

Include Indoor Air Quality Expertise

The architect, as the lead designer, has the ultimate responsibility for a building's design, and for determining that the completed building fulfills the design intent. Normally, the design team consists of school district representatives, architects, engineers, site council representatives, interior designers, specification writers, specialized consultants, and construction experts.

In situations where the architect's staff does not have the necessary expertise to address certain indoor air quality issues, then specialized consultants should be brought onto the design team for support. Architects and/or team members may need training or outside consulting expertise not typically provided in school design projects to address indoor air quality issues.

Demonstrated knowledge and experience in indoor air quality at this stage will improve the team's ability to prevent indoor air quality problems from developing once the project is complete. As part of the process for procuring design team services, the school district should consider qualifications and experience to address indoor air quality issues as described in this Manual.

The design team will depend upon the direction and advice of the school district administrators, and will work with the school IAQ coordinator in assuring that indoor air quality issues are addressed. The design team will also consult with building material, equipment, and furnishing manufacturers and suppliers to obtain information on product emissions. This information will be used to define specifications for materials to reduce indoor air contaminant emissions in the occupied building.

In addition, throughout the design process, the design team should periodically meet and consult with the local health department, planning department, building department, fire department, and other local agencies to identify issues of concern, legal requirements, and review and approval processes.

Preparing an Indoor Pollutant Source Control Plan

Developing Indoor Air Goals

The project designer and/or school district should prepare and implement an indoor pollutant source control plan to address indoor air quality design issues within the building. As a first step in preparing the plan, the project designer should work with the school district to define indoor air goals and objectives for the building project. A clear understanding of building occupancy and intended uses, and potential changes over time will help the design team consider potential contaminant sources in each space or section of the building and consider control strategies to deal with each source.

Space planning can separate incompatible functions, isolate pollutant generating activities, and buffer activities which are sensitive to air pollution. Goals and criteria may be established for ventilation systems, material selection, and maximum permissible air contaminant concentrations.

As an example, it may be stated that the building objectives are to comply with ASHRAE Standard 55-1992 to meet thermal comfort needs, as well as Chapter 51-13 WAC and ASHRAE Standard 62-1989 for adequate outdoor ventilation and air distribution. To meet these standards, consideration is then given to the size and layout of HVAC zones, heating and cooling equipment capacity, and humidification or dehumidification equipment.

The plan should then address the elements of building design and construction relevant to indoor air quality as outlined below. These elements should take into consideration the applicable recommendations in this Best Management Practices Manual, applicable governmental regulations, and relevant professional organization standards and guidelines (including those prepared by ASHRAE):

- ***Site and facility planning***--including setbacks; landscaping; birdproofing; building shape and orientation; infiltration protection; parking and loading patterns; roofing design; and management of other on-site contaminant sources

HVAC design--including location of outdoor air intakes and exhausts; HVAC sizing and air flow requirements; compatibility with uses and potential changes over time; use of natural ventilation; control of microbial growth; space planning and ventilation for special use areas; duct insulation; air filtration

- and cleaning; control of interior temperature, humidity, and other air quality conditions; selection and placement of control systems; type of HVAC system selected; and measures to be taken to facilitate operation and maintenance, and

- ***Selection of materials, interior finishes, and furnishings to reduce building emissions***--targeting materials and products; collecting product information; using emission rate guidelines; obtaining test data for product emissions; pre-conditioning of furnishings and materials; air flushing of the building before occupancy; controlled application of wet materials; and disclosure requirements for cancer-causing agents and reproductive toxins.

Complying with Codes and Standards

During school siting, design, construction, and operation, compliance with codes and standards is essential. Designers, contractors, and school building officials should be familiar with applicable state and local codes and standards.

In Washington State, the Washington State Ventilation and Indoor Air Quality Code (Chapter 51-13 WAC) governs certain aspects of indoor air quality. Chapter 51-13 WAC includes requirements for outdoor air ventilation of buildings, and defines radon protection construction standards.

ASHRAE Standards and Guidelines

Although few standards exist specifically to address indoor air quality concerns, ASHRAE has produced several standards and guidelines which are specifically directed at indoor air quality, some of which are incorporated into Chapter 51-13 WAC. (Note: ASHRAE makes a distinction between standards and guidelines--although both are voluntary, guidelines are less definitive than standards, and often encompass a variety of approaches. ASHRAE standards and guidelines are cited throughout this section and listed in the reference section).

Standards for School Indoor Air Quality

No standards for indoor air contaminant levels have been established specifically for children in schools. However, various governmental agencies and professional organizations have recommended concentration limits for various contaminants for affected populations. Differences among these concentration limits stem from underlying differences in populations the guidelines are intended to protect, the level of protection desired, and differing assumptions concerning exposure.[2]

Contaminant concentration limits designed to protect the public health are uniformly more stringent than those established for occupational settings. This is largely due to the fact that public health guidelines are usually designed to protect the entire public, including the elderly, the young, and some individuals with particular health sensitivities, and exposures are assumed to be involuntary. Occupational limits, on the other hand, are intended to protect a relatively healthy adult workforce in settings where exposure is assumed to be voluntary. One summary of the recommended guidelines and standards for human exposure to various air contaminants may be found in Appendix C of ASHRAE Standard 62-1989, *Ventilation for Acceptable Indoor Air Quality*.[2]

This Best Management Practices Manual does not specify numerical standards for indoor air contaminants. However, the Manual recommends many building design and construction practices as well as building operation and maintenance practices that should be used to help ensure good indoor air quality in schools. As appropriate, these practices should be adopted for use at a school, and adherence to these practices and associated schedules can be used as an indicator of indoor air quality. Although numerical standards for indoor air quality are not established, this Manual does suggest specific emission levels that may be used for certain materials and furnishings that will be installed in new or remodeled buildings (see page 6-40).

Required reviews, permits, and approvals must be obtained from all state and local authorities. Note that the local health department is specifically authorized to review and approve proposed school development sites, as well as construction plans and specifications, and to conduct pre-occupancy and follow-up inspections to ensure conformance with approved plans (WAC 246-366-030; -040). The focus of the health department's participation is health and safety, although it is not responsible for ensuring compliance with codes under the jurisdiction of other agencies. With respect to indoor air quality health and safety issues, the local health department may choose to focus its attention on issues related to temperature, odors, ventilation, and indoor air contaminants (WAC 246-366-080;-090;-140). The local health department should be consulted early in the siting and design process to minimize any delays in review and approval throughout the project.

Assessing Budget and Schedule Impacts

Indoor air quality management expenses should be projected during the budgeting process for school development, renovation, and operation and maintenance. It can be expected that promoting good indoor air quality may increase costs during the siting, design and construction stages. The primary design professional should take the lead in preparing estimates, with input from other members of the design team. Costs related to improving indoor air quality may include the following:

- site evaluation and documentation
- design and installation of improved air handling, cleaning, distribution, and monitoring components
- possible increased costs associated with building components, fixtures, and furnishings which produce lower emissions, or maintenance products which produce lower emissions
- commissioning costs
- air quality monitoring during HVAC system commissioning and initial occupancy, and
- additional costs of consultants during site evaluation, design, construction, commissioning, and operations. Services not normally part of basic design services offered to school districts include ESAs, climate assessment, assessment of radon and other environmental factors, preparation of an indoor pollutant source control plan, coordination with the school IAQ coordinator, alternative materials research, and indoor air quality design documentation.

Caution should be used in preparing and interpreting cost estimates for addressing indoor air quality concerns. Higher initial capital and related costs may be offset by reduced replacement costs, lower long-term operation and maintenance costs (including energy costs), fewer unanticipated costs for correcting indoor air quality problems, and higher employee and student productivity. It is important to estimate all the costs (consider life cycle costs) before making purchasing decisions which may influence indoor air quality.

It is also important to budget sufficient *time* to complete each phase of the project. Additional time for evaluating sites, preparing plans, and evaluating materials should be scheduled into the pre-design and design phases. In addition, sufficient time should be planned for ventilating buildings and furnishings prior to installation and/or occupancy.

Site and Facility Planning

Using the guidance for site assessment and evaluation provided in Section Five of this Manual, the design team can develop a site plan to minimize the impact of outdoor air pollution on indoor air quality. Major elements of site design that can improve indoor air quality include setbacks, birdproofing, landscaping, shape and orientation of the building shell, parking and vehicle circulation, roofing design, and management of other contaminant sources in the vicinity of the site.

Setback

Schools located near streets and highways may have elevated levels of lead and carbon monoxide in the indoor air. Road surfaces can also produce dirt and dust, and may mobilize lead and pesticides which may enter a school building. Factors that influence the potential impact of roadways are the proximity of the roadway, prevailing meteorological conditions, the type of road surface, number and types of vehicles, and vehicle speeds.[3]

Setbacks protect building structures from vehicle emissions and other nearby off-site sources. For sites near roadways that are heavily traveled, a small increase in setbacks can result in a relatively large decrease in contaminant concentrations.

Contaminant concentrations decrease with increasing distance from the source. This occurs because contaminants tend to disperse, producing dilution as the distance increases.

The setback distances should be determined on a case-by-case basis, depending upon the property size and location, proximity to off-site contaminant sources, the degree to which off-site contaminants are of concern, and other relevant design factors.

Landscaping

Lawns, shrubbery and trees must be used carefully since they offer both advantages and disadvantages to the building environment. Some vegetation can reduce wind-induced air infiltration and capture particulates carried by outdoor air. On the other hand, vegetation can be a significant source of contaminants. It is important that plants and soils not be placed too close to air intakes or other building openings. Molds, fungi, other microbial activity, and pollen can become indoor air contaminants. In addition, at maturity, some plants can block air flow.[3]

In addition, landscaping should be planned such that routine maintenance (such as lawn mowing, or applications of carefully selected fertilizers or pesticides) will not generate air contaminants that can be easily drawn into building air intakes. Pesticide use may be minimized or avoided by selecting plants which are resistant to pests.

Birdproofing

Perching, roosting, and nesting locations may attract birds and lead to accumulated wastes that can disrupt proper operation of HVAC systems, promote microbial growth, and cause human disease. Grilles protecting air intakes should be bird-proof to prohibit perching, roosting, or entry. Horizontal grilles create the most serious problems, because droppings can fall into the outdoor air intakes.

Building Shape and Orientation

Structures should be arranged to allow for the movement of prevailing winds to avoid stagnant air and the trapping of pollutants. Exhausts should be located to allow prevailing winds to sweep away exhaust plumes from the building.

Similarly, the location and orientation of outdoor air intakes should be designed to avoid the entry of contaminants from the building exhaust, or from the exhaust of other buildings.

Infiltration Protection

The influence of weather conditions (e.g., windspeed and direction, temperature and related stack effect) on indoor air quality is strongest when buildings are constructed with high infiltration rates. However, infiltration is generally not a problem in new school construction due to the requirements of the Washington State Energy Code. Infiltration can raise or lower contaminant levels depending upon outdoor air quality and pressure relationships in the building. High infiltration rates also increase energy costs and make it more difficult to control indoor air temperatures and humidity, which can lead to discomfort for occupants. Infiltration can also bring in moist air, which can condense and contribute to microbial growth.

For new or remodeled buildings, the overall conceptual design should be analyzed to provide protection of the building occupants against infiltration of contaminants from outside sources, such as parking areas, loading docks, building exhausts, plumbing vents, and drain piping. In addition, the conceptual design should provide protection of occupants from infiltration of radon and other soil gases.[4,5]

Parking and Loading Patterns

Any parking areas, garages, or auto shops should be designed to vent vehicular exhaust in such a way that it does not become drawn into building air intakes. The design should also protect the building from infiltration of pollutants created by vehicles in the facility[6].

Exhaust from vehicles using the loading dock should also be vented to prevent infiltration into the building, and to prevent emissions from being drawn into the building air supply system[6].

Large on-site parking areas, with vehicles running or idling at low speeds (including automobile and school bus loading/unloading zones) generate considerable amounts of emissions. Vehicle parking, loading, and roadway areas should be located away from building openings or outdoor air intakes. Orientation and shielding options may also be used to minimize the potential for contaminant entry.

Once the building is occupied, other measures can be used to minimize the intake of vehicle exhaust into buildings. These measures include instructions or signs requesting vehicle operators to shut off engines, rather than idling engines in specific areas.

Roofing Design

Special precautions should be taken to ensure that new roofs are adequately sloped to drain water. Poorly designed or drained roofs may be a potential source of poor indoor air quality. Flat roofs invariably collect water, and after leaking, may require extensive reconstruction or repair using adhesives or tars. These materials often contain toxins and may be harmful if fumes enter the building, especially during installation or repair.[2]

Stagnant, standing water on roofs can also support microbial growth that can be drawn into building air systems. Leaks can damage tiles, rugs, walls, and internal spaces. Fungi and bacteria can develop in this moist environment and contribute to allergic responses or respiratory disease.[2]

Rainwater should be drained and channeled away from the building and all walkways, especially those walkways at school building entrances. This will help avoid the entry of water and debris into the building through infiltration or by students, staff, or visitors.

Management of Other On-Site Contaminant Sources

Other features of the site design may be sources of indoor air contaminants. Examples include decorative elements such as flower beds, and functional items such as dumpsters or underground fuel tanks. Locations should be selected that fulfill the intended function while reducing the potential for contaminant entry.

If outdoor gas and particulate contaminant concentrations are known to exceed the maximum levels established by the EPA National Ambient Air Quality Standards (NAAQS), consideration should be given to pre-treatment of the air by filtration or sorption before being used in the ventilation system.[6] The NAAQS are presented in Table 6-1.

HVAC Design Recommendations

Design and Location of Outdoor Air Intakes and Building Exhausts

The building outside air supply intakes should be located so that they do not receive air released from building exhausts, loading docks, or nearby buildings.[6] In addition, building air intake and exhaust locations should be coordinated to optimize the quality of outdoor air intake for buildings on *adjacent sites*.[4]

Although exhaust gases may contaminate intake air for some specific wind directions, careful building design can minimize such contamination in mechanically ventilated buildings. A good design recommendation is to place the indoor air intake on the *lower* one-third of the building and the exhausts on the *upper* two-thirds. It has been found that minimal mixing of surface flows of air occurs between of the upper two thirds and the lower one third of the building.[7] However, caution should be used in selecting air intake locations, since an air intake located too close to the ground may be more susceptible to intake of dust and debris from ground-level sources, and may be more easily vandalized.

When exhaust outlets are located on the roof, aesthetic enclosures which restrict or impair the exhaust should be avoided. If enclosures are desired or required by local code, they should be of the open-louvered type which allow horizontal winds to flush the enclosure. Intakes should not be located within the enclosure.[8]

Table 6-1: National Ambient Air Quality Standards

	Long Term		Short Term	
Contaminant	**Concentration:**		**Concentration:**	
	ug/m3	*ppm*	*ug/m3*	*ppm*
Sulfur dioxide	80[1]	0.03[1]	365[3]	0.14[3]
PM-10[8]	50[1]	--	150[3]	--
Carbon monoxide[6]			40,000[5]	35[5]
Carbon monoxide[6]			10,000[4]	9[4]
Ozone[6]			235[9]	0.12[9]
Nitrogen dioxide[7]	100[1]	0.055[1]		
Lead[7]	1.5[2]	--		

[1] Average for 1 year.
[2] Average for 3 months.
[3] Average for 24 hours.
[4] Average for 8 hours.
[5] Average for 1 hour.
[6] Long Term standards are not established.
[7] Short Term standards are not established.
[8] Particulate matter less than or equal to 10 microns.
[9] Applies when one or more hourly ozone concentrations exceed this value during three days in a three year period.

Rain caps which direct the flow of exhaust air back towards the roof should be avoided. These caps can greatly reduce the dilution of exhausted air.[8]

When possible, exhaust outlets and stacks should be placed on the predominant downwind side of the building and intakes on the upwind side. Stacks should be placed as far away from intakes as possible.[8]

Ample stack height should be provided. It is advisable to ensure that stacks are at least 10 feet away and two feet above an air intake. Stacks within 50 feet of the roof line or an air intake should be at least 10 feet tall. In no case should stacks be less than seven feet tall, since shorter stacks may present a risk to maintenance people working near the stacks.[8]

Cooling towers should be placed at least 25 feet from outdoor airintakes.[8]

Some studies have shown that the most significant factor in the re-entry of exhaust pollutants is the imbalance between makeup and exhaust air flow rates. This imbalance can create infiltration at leakage sites over the entire building surface. As required by code, buildings should have balanced ventilation. With balanced ventilation, about one percent of the exhaust gases typically return to the building. However, in buildings with ventilation imbalance, and where building intakes and exhausts are close together, the re-entry of exhaust gases may be as high as 10 to 15 percent. A major factor causing ventilation imbalance is the use of exhaust hoods with high flow rates. The suction caused by such hoods pulls in exhaust gases through building cracks and openings. Good engineering design will ensure sufficient makeup or intake air to compensate for losses from hood and other exhausts.[7]

HVAC Sizing and Air Flow Requirements

The HVAC delivery system should be sized to provide adequate ventilation to the building population, based upon*maximum* occupancy loads as specified by state and local building codes. In other words, to the extent feasible, it is important to design for potential increases in student enrollment, so that the building HVAC system will be able to provide sufficient ventilation to all building occupants, even in classrooms housing more students that originally expected or desired.

As noted above, outdoor air must also be sufficient to replace the air exhausted by the cafeteria, industrial arts areas, science laboratories, rest rooms, showers, and other special purpose areas. Additionally, the air-movement capability of the HVAC system should be great enough to provide effective air flow *at the occupants'breathing zone* , which is from three to six feet above the floor in most school areas. In special areas, such as swimming pools and wrestling rooms, the breathing zone is much closer to the water surface or floor level, respectively.[4,6]

Table 6-2 identifies the outdoor air ventilation rates (amount of fresh air per occupant) for educational facilities, and special activities within educational facilities. These ventilation rates are specified in the Washington State Ventilation and Indoor Air Quality Code (WAC 51-13-304), and are based upon ASHRAE Standard 62-1989. Air flow provided by air handling units should provide at least 15 cubic feet per minute (cfm) per person of outdoor air, or greater as specified in WAC 51-13-304. Air handling units should have the ability to provide 100 percent outside air, although water source heat pumps are unable to independently provide 100 percent outdoor air. If water source

Table 6-2: Outdoor Air Ventilation Requirements for Educational Facilities

Area	Estimated Maximum Occupancy (persons per 1000 square feet or 100 square meters)[1]	Outdoor Air Requirements (cubic feet per minute per person)
Classroom	50[4]	15
Laboratories[2]	30	20
Training shop	30	20
Music room	50	15
Library	20	15
Offices	7	20
Conference room	50	20
Corridors		0.10 cfm/sq. ft.
Auditoriums	150	15
Gymnasium spectator areas	150	15
Gymnasium playing floor	30	20
Darkrooms	10	0.50 cfm/sq. ft.
Public restrooms[3]		50
Locker rooms		0.50 cfm/sq. ft.
Cafeteria	100	20
Kitchen	20	15
Swimming pools		0.50 cfm/sq. ft.

[1] Net occupiable space.

[2] Special contaminant control systems may be necessary for processes or functions including laboratory animal occupancy.

[3] Per water closet or urinal.

[4] Although the code specifies a maximum of 50 occupants per classroom, a more realistic maximum level is approximately 30 occupants per classroom

heat pumps are used, supplemental ventilation should be available to meet outdoor air supply requirements.[6]

The amount of outdoor air listed in Table 6-2 assumes good mixing with recirculated air in the supply air system, and uniform distribution within the occupied zone. *Ventilation effectiveness* can be defined as the ratio of the amount of outdoor air *reaching* the occupants compared to the total amount of outdoor air *supplied* to the space. Ideally, the ventilation effectiveness of a space should approach one-to-one, or unity (1.0). If the ventilation air moves from supply outlets to exhaust grilles without reaching the occupants, the ventilation effectiveness will be reduced. Barriers and partitions installed in rooms can also reduce ventilation effectiveness.[3]

Many buildings are designed with supply air outlets and return air inlets located at ceiling level. This placement can lead to *short circuiting* of air. As the air moves across the ceiling, much of the room (especially the occupants' breathing zone) is left with poor ventilation. Designers of new or remodeled school buildings should recognize the potential for short circuiting and avoid designs in which it is likely to occur.[10]

Peak carbon dioxide concentrations above 1000 parts per million (ppm) in the breathing zone indicate ventilation problems or an outdoor air contamination problem from traffic or other combustion sources. Carbon dioxide concentrations at this level or higher may result in complaints about indoor air quality. Such complaints are not the result of carbon dioxide levels, but may result from the buildup of odors or other indoor air contaminants in the room. Carbon dioxide concentrations below 1000 ppm generally indicate that ventilation is adequate to deal with the routine products of human occupancy.[9]

Compatibility with Occupancy and Use Changes over Time

Design of the internal HVAC delivery system should incorporate the ability to easily redirect the internal air flows as occupancy and activity patterns change over the life of the building. The HVAC system should be designed and balanced to deliver specified air flows to the occupants' locations, taking into account any interference which may be created by work stations, partitions, and other furnishings. Occupied zones should not have stagnant air.[6]

Compatibility with Natural Ventilation

Windows that open and close allow natural ventilation. This can enhance the occupants' sense of well being and feeling of control over their environment. Unfortunately, there is little research measuring the effectiveness of natural ventilation on reducing indoor contaminant levels.[7]

In most situations, a sealed building can provide better indoor air quality than a building with operable windows. Uncontrolled infiltration and air entry allows outdoor air contaminants to bypass filters and air cleaning equipment; it can also disrupt the balance of the mechanical ventilation system and conflict with energy conservation goals. However, some school districts may choose to allow for natural ventilation in the building design, since it may enhance occupant comfort and satisfaction with the indoor environment, and can provide supplemental ventilation when necessary or desired.

If natural ventilation will be used to supplement mechanical ventilation, there are several building design issues that should be addressed. Openings for outdoor air should be below head height (three to six feet) in the occupied zone. Windows, ventilating sash, and other openings in the exterior walls should be selected to minimize drafts on occupants seated nearby. In addition, they must be adjustable and close tightly.[11]

Siting and configuration of the school can enhance the effectiveness of natural ventilation. Siting and configuration recommendations include the following: orient major facades toward prevailing winds; provide for exterior exposures for all occupied spaces; to the extent possible, design exterior openings on opposite faces of the building to create cross circulation; limit building depth; avoid the intrusion of traffic or other noise through wall openings; screen to prevent the entry of insects, birds, and rodents; avoid using natural ventilation where dust-free environments are vital, such as computer rooms; and avoid placing windows next to industrial process venting, odor sources, urban traffic, and building exhausts.[11]

Microbial Growth through HVAC Design

The design of the HVAC system should assist in the prevention and removal of microbial growth. Microbial contamination can originate from water reservoirs in the air conditioning distribution system and cooling towers. Condensate pans in air supply units should be designed for self-drainage to preclude the buildup of such contamination. Design of condensate pans should take into account the slope of the pan, drain location (bottom is preferred to side).

draining into another drain with a trap, and ease of access for inspection and maintenance.[2,3,4]

Maintenance of interior environmental conditions should comply with ASHRAE Standard 55-1992, *Thermal Environmental Conditions for Human Occupancy*. Relative humidity should not exceed 70 percent over which microbial growth would be encouraged. Provisions should be made to maintain relative humidity between 30 and 60 percent.[6,12]

The cooling coil should be designed to prevent carryover of water condensate. This may be accomplished by maintaining proper air velocities across the coil, or by using water eliminators. Carryover of water condensate can contribute to microbial growth which will be distributed through the HVAC system.

Special attention to material selection is also warranted where high air moisture levels are expected, such as in kitchens, showers, or downstream from cooling coils in air handlers. In these high risk areas, easily cleanable, smooth surfaces are recommended.

Ventilation for Special Use Areas

The overall design of the building exhaust system should ensure direct exhaust of areas where odors, dust, and other contaminants are created. Areas requiring direct, local exhaust should also be maintained under negative pressure to help prevent the leakage of pollutants into other occupied areas of the building. These areas should be located where emissions can be isolated and controlled.[4,9]

Activities for which local exhaust is necessary include science demonstrations and projects, chemical and housekeeping material storage, kiln firing, welding, internal combustion engine use, spray painting, cutting and milling, cooking, photo processing, some photocopying operations, rest room exhaust, and dryers.[2]

Particulate and gaseous contaminants from local sources within a space should be captured, collected, and removed *as close to the source as practical*. This includes bench and hood exhausts in chemistry laboratories, cleaning supply rooms, photography darkrooms, art studios, and vocational shops.[3]

If dangerous chemicals are used in any building activity and directly exhausted (such as a science lab), a decision should be made concerning the need to filter or scrub exhaust contaminants in light of land uses and activities downwind of the building, and to meet air quality standards.

Any regulated new or modified outdoor air pollutant source must:

- not cause or contribute to a violation of any ambient air quality standard
- not violate any applicable emission standard, and
- use best available control technology for air emissions.

The project manager or designee should contact the Washington Department of Ecology or the local air pollution control authority regarding requirements for preconstruction permits for stack emissions (from boilers, heaters, power generators, for instance) and from building exhausts from certain special use areas.

A more detailed discussion of ventilation recommendations and good maintenance and operation for several special use areas is presented in *Section Ten: Controlling Contaminant Sources in Classrooms, Offices, and Special Use Areas*.

Duct Insulation

Supply and outside air duct work must be insulated, as required by code. However, it is important to minimize or eliminate the use of internal acoustical duct liners and employ other means of noise reduction which do not involve contact of the building air supply with exposed fibrous materials. Fibrous insulation may be a site for microbial growth in the HVAC system, may emit VOCs, and if exposed or abraded, may shed particles into the air, presenting a health hazard.

Particular attention should be paid to keeping the duct insulation dry during construction. Ductwork is often installed before the building is watertight, and insulation may be wet for long periods of time before the air handlers are operational, and able to dry the insulation out. It is advisable to discard any duct insulation that shows signs of mold growth or has been saturated for extended periods of time.

Sound attenuation devices should have a non-fibrous lining, or as an alternative, should have a coating over all exposed fibrous surfaces. If coated fibrous liners are used it is important that the design prevent air velocities from exceeding ASHRAE and manufacturer standards, since high velocities may abrade surface coatings, expose fibers, and distribute fibers through the building.

Noise from equipment within the classroom, emanating from air outlets, or from ceiling systems can be disruptive. The ASHRAE Fundamentals Handbook recommends a classroom sound criterion not to exceed NC-30 for an acceptable noise level.[11] The Washington State Board of Health Primary and Secondary School Regulations (WAC 246-366-110) are less stringent, allowing a background sound limit of NC-35. At a minimum, system and equipment selection and sound attenuation techniques should limit HVAC system noise to those specified by state health regulations. Compliance of installed units with state regulations should be verified by the design consultant, contractor, or by the local health department.

All duct insulation must meet the requirements of the National Fire Protection Association (NFPA-90A) for flame spread and smoke contribution. Insulation R-value should be consistent with requirements of the Washington State Energy Code.

Air Filtration and Cleaning

Filters should be selected for their ability to protect both the HVAC system components and general indoor air quality. As the efficiency of filters increases, so does their cost. However, in many buildings, the best choice is a medium efficiency, pleated filter because these filters have a higher removal efficiency than low efficiency filters, yet they will last longer without clogging than high efficiency filters. Medium efficiency filters have an ASHRAE Dust Spot rating of 30 percent to 60 percent.[9]

To maintain the proper airflow and minimize the amount of additional energy required to move air through these higher efficiency filters, *pleated-type extended surface* filters are recommended for use where possible. In building areas that are designed to be exceptionally clean (for instance, computer rooms), the designers may specify use of both a medium efficiency pre-filter and a high efficiency extended surface filter (ASHRAE Dust Spot rating of 85 to 95 percent). Some manufacturers recommend high efficiency extended surface filters (ASHRAE Dust Spot rating of 85 percent) without pre-filters as the most cost effective approach to minimizing energy consumption and maximizing air quality in modern HVAC variable air volume systems that serve office environments.[9]

One of the benefits of selecting medium to high efficiency filters is to reduce the spread of infectious diseases, although exclusion of sick teachers, staff and students from the building is preferred. As described in Section Two of this Manual, some microbial diseases

Using Medium to High Efficiency Filters Reduces the Chance of Spreading Illness

can be transmitted through the indoor air. These include tuberculosis, influenza, measles, and the common cold. A principle means of transmission of viruses and bacteria is by droplet nuclei. These start as moisture droplets containing organisms expelled by infected individuals, dry out, then the residue is carried through the building by air currents.[13]

Typically, these residues are one to five microns in size, and they can remain suspended in the air for days. These pathogens and allergens are respirable, and can be removed from the air by some air filters. This reduces the possibility of transmission from an infected person to others susceptible to infection.[13]

Particles in the size range of droplet nuclei can be substantially removed from the recirculated or mixed air stream by medium to high efficiency filters (although a high efficiency filter should be used for removal of tuberculosis viruses). A 60 to 65 percent dust spot efficiency filter (ASHRAE Standard 52.1-1992) will remove 85 percent or more particles of an average size of 2.5 microns. An 80 to 85 percent efficiency filter will remove 96 percent of 2.5 micron size particles.[13]

Air filters will perform their designed function provided that they are properly selected for the HVAC system, installed correctly, and replaced when necessary. Air filters must be properly fitted to prevent air by-pass. Although a regular inspection and maintenance program for air filters is appropriate, it is recommended that pressure gauges be installed on central systems to detect clogged filters.[5,9] These gauges indicate pressure drop across the filter face and are easily monitored to determine the need for filter replacement. As the filters capture dirt, airflow resistance across the filter increases, decreasing the quantity of air moving through the system.

As noted above, outdoor air employed for ventilation and dilution of contaminants should not exceed concentration limits stated in the National Ambient Air Quality Standards as established by the EPA. Pre-treatment of air through filtration or sorption may be used to reduce contaminants to acceptable levels (see Table 6-1).[2] When necessary, dust collectors should be used when the dust loading equals or exceeds 10 milligram per cubic meter, or 4 grains per 1000 cubic feet.

Control of Interior Temperature, Humidity, and Other Air Quality Conditions

Comfort in school buildings is affected by a number of factors. These include temperature, thermal radiation (such as heat from direct sunlight), humidity, the speed of the air, the occupants' level of activity, the ages, sex, and physical conditions of the occupants, and the type and quantity of clothing the occupants are wearing. ASHRAE Standard 55-1992, *Thermal Environmental Conditions for Human Occupancy*, recommends temperature ranges which should be maintained to keep building occupants comfortable. In winter, the recommended temperature range is 68 to 75 degrees F. for people doing light, primarily sedentary activities. In the summer ASHRAE recommends a temperature range of 73 to 79 degrees F.[12] In Washington State, some areas cannot achieve these recommended temperature ranges without air conditioning (mechanical cooling).

The level of relative humidity directly affects the temperature ranges found to be acceptable by occupants. Assuming other factors concerning occupant comfort remain constant, a combination of temperature and relative humidity can lead to the definition of an operative temperature to help define comfort boundaries. ASHRAE Standard 55-1992 describes the operative temperature ranges for lightly clothed, sedentary adults.[12]

For thermal comfort, the optimum range for relative humidity is 40 to 60 percent in the summer, and 30 to 50 percent in the winter. From a health standpoint, higher humidity levels (above 60 percent) can encourage microbial buildup. Dust mites, bacteria, and fungi all thrive under moist, humid conditions. For this reason it is appropriate to maintain the relative humidity below 60 percent throughout the year. At the other extreme, very low humidity can create discomfort, respiratory problems, and aggravate allergies in some individuals. In the winter, it is advisable to maintain relative humidity at 30 percent or above.[2]

As noted previously in Section Six, ventilation equipment should be constructed and maintained to minimize the opportunity for growth and dissemination of microorganisms through the system. Construction should comply with applicable codes.[14]

Steam humidifiers must use clean steam, rather than treated boiler water, so that occupants will not be exposed to chemicals. Systems using media other than clean steam must be maintained in accordance with the manufacturer's recommendations to reduce growth of microorganisms. A maintenance schedule should be established for humidifiers after installation.[9]

Air temperature within a room generally increases from floor to ceiling. If a sufficiently large difference exists in the occupied zone so that the temperature at the head is more than 5 degrees F. higher than near the floor, discomfort may result. Good air mixing, and insulation of wall and floor surfaces can reduce temperature differences.[3]

While little or no air movement may be necessary to achieve thermal comfort, the dilution of contaminants within the occupied zone or subzones will require effective dilution with adequate amounts of air movement or circulation. Supply and return air distribution systems serving occupied zones should be designed and operated to achieve effective ventilation and temperature uniformity during all operating modes during the occupancy period. In winter, average air movement above 30 feet per minute in the occupied zone may result in uncomfortable drafts.[3]

Building spaces with dissimilar heating and cooling load characteristics, such as amount of window exposure, occupancy patterns, and internal energy sources should have independent means of temperature control. Interior spaces generally should not be on the same temperature control zone as spaces on the perimeter of the building. In winter, interior spaces may require cooling while perimeter spaces may require cooling or heating. Interior spaces such as offices may be grouped on a common zone when the thermal load characteristics and occupancy profiles are quite similar. Classrooms, libraries, and gymnasiums should be zoned separately. Systems should monitor temperatures in each occupied space to ensure satisfactory thermal performance.[3]

Selection and Placement of Control Systems

Careful attention should be given to the selection of temperature and other HVAC system controls for new or renovated school buildings. The following factors should be considered when selecting HVAC system controls:

- the sophistication of the control system should be matched with the current or anticipated technical ability of the school's HVAC system operation personnel

- the resources and capabilities of district staff to respond promptly to a detected error or failure, and to perform preventive maintenance--a system capable of producing a failure analysis may not be beneficial if responses cannot be provided in a timely manner

- the district's experience with existing controls in maintaining comfort in its school buildings--time spent reviewing the adequacy of existing control systems will help establish design criteria for the new or remodeled building, and

- control systems should be selected that are of high quality and capable of working in harmony with the HVAC system to produce a high level of indoor air quality.

Placement of temperature controls is important. Thermostats should not be located in direct sunlight, above a heating element or a heat emitting appliance, in an inaccessible location, or in a zone outside the area served by the air handling unit the thermostat controls.

Advantages and Disadvantages of HVAC Systems for Classrooms

A good description of HVAC systems that may be used in schools is presented in a document entitled *Selecting HVAC Systems for Schools to Balance the Needs for Indoor Air Quality, Energy Conservation and Maintenance*, by the Maryland State Department of Education. A summary of HVAC system options with a brief discussion of their advantages and disadvantages is provided here to assist school facility design teams.[11]

Unit Ventilators[11]

Unit ventilators have been one of the most popular methods of heating, cooling, and ventilating schools. They are usually located on room floors at the outside wall beneath a window, but they may be ceiling mounted.

Advantages of unit ventilator systems include:

- they are developed specifically for classroom use with appropriate ruggedness and aesthetic features

- there is no recirculation of air between classrooms

- they have independent classroom control and operation

- there is effective room air distribution capable of offsetting downdrafts at cold perimeter walls

- there is a constant volume of air flow in each room served

- duct work and central air handling equipment are not needed

- one inoperative unit does not affect the entire system, and
- it is easy to plan for future additions.

Disadvantages of unit ventilator systems include :

- controls for heating, cooling, economizer and ventilation are required in every unit
- excess outdoor air may blow in during cold windy weather through the ventilation damper, causing drafts and risk of coil freezing
- filters are limited to one inch thickness, which limits the level of filter effectiveness
- units can be noisier than allowed by state code (NC 35). Additional costs may be incurred to bring unit ventilators into compliance with the code (compliance should be verified)
- since maintenance is normally performed in the classroom, it often has to be scheduled when class is not in session
- unit components can be difficult to clean
- when the units are delivering large quantities of outdoor air, relief of air from the building is needed to avoid overpressurization
- outdoor air must be balanced in each unit to assure proper ventilation
- about one to two percent of classroom space must be dedicated to floor-mounted units
- easy access to units and controls provides an opportunity for misuse or abuse of equipment
- unit ventilators cannot be used in interior classrooms, and
- air flow can be easily obstructed by objects placed on top of the units or by blocking the air intakes.

Variable Air Volume Systems[11]

Variable air volume (VAV) systems are frequently selected for school HVAC systems. These systems serve multiple rooms, where the volume of the air delivered to each room is governed by the room's thermostat. Heat is provided by a terminal-located heating coil. Fans must be installed in terminal units to provide a constant air supply. Air is supplied through registers or diffusers located on the ceiling or high on the wall.

Features which favor VAV systems include:

- properly designed and maintained, the VAV system provides the greatest level of indoor air quality of all systems
- system equipment is primarily centralized, so maintenance in every room is minimized
- medium to high efficiency filters can be used
- interior and perimeter rooms can be supplied by the same system
- these units are efficient, since there is less fan and reheat energy used than most other systems
- since the system is primarily centralized, it can be remotely located and secure from tampering or vandalism, and
- outdoor air can be automatically adjusted to compensate for changes in total supply air flow and building population.

Some of the disadvantages of VAV systems include:

- The return air is transmitted through plenum spaces--plenum spaces can attract dirt and dust, compromising air quality
- classroom relative humidity is not directly controlled
- maintenance of terminals can be difficult if they are located above classroom ceilings
- a fan and filter must be maintained at every terminal unit
- fan-powered units can be noisy if located above room ceilings

- air distribution ducts take up ceiling space, and may be especially costly to install as an upgrade in existing buildings

- the number of units can only be expanded economically if the expansion was planned for in the initial capital project, and

- performance of the whole system may be compromised if one or only a few key components malfunction.

Zone Systems[11]

A *single zone system* usually serves one room, and is often located on the rooftop. This system should be heavy-duty for school use. Air flow is constant, with the temperature varied by thermostat control.

Advantages of the single zone system include :

- the initial cost is often less than other systems for smaller schools

- central refrigeration and boiler plants may be unnecessary

- medium efficiency (30 to 60 percent dust spot) filters may be used

- additional single zone systems can be readily added to serve new spaces

- except for thermostats, these units are remote and relatively safe from tampering, and

- remote locations can be controlled through a centralized control system.

Disadvantages of single zone systems include :

- for larger facilities or those with multiple levels, the space needs for units and ducts may be impractical

- relative humidity may not be adequately controlled

- rooftop locations may be less accessible, and lead to undesirable noise and roof leaks from maintenance traffic

- multiple rooftop units may be unsightly, and

- refrigeration in these systems is less likely to be as energy efficient as central chillers.

Multizone Systems[11]

Multizone units can serve six or more rooms at a time, and are often designed for rooftop mounting. If cooling is provided, the Washington State Energy Code requires use of a three-deck unit.

The advantages of multizone units are similar to single zone units, with the following exceptions:

- initial costs can be lower than single zone units if clusters of classrooms will be served

- acoustics, aesthetics, and maintenance is more manageable since fewer units are needed than with single zone systems

- with reduced cooling, part of the air continues to be dehumidified by the cooling coil, providing better humidity control.

Disadvantages include:

- requirements for more extensive ductwork to classrooms, and

- less flexibility for accommodating space changes or expansion.

Water Source Heat Pumps[11]

Water source heat pumps are units which can be selected to serve each school room. The heat pumps are connected by a low temperature water loop (65 to 95 degrees F.). The heat pumps extract or reject heat to the loop which is maintained at temperature by a boiler or cooling tower.

Advantages of heat pumps include:

- heating or cooling of each space separately, year round

- energy efficiency

- flexibility in location, potentially serving interior and perimeter rooms

- the supply air is constant, and

- closet locations for units can reduce noise.

Disadvantages of water source heat pumps include :

- these units cannot provide 100 percent outdoor air
- the requirement for preconditioning of the outdoor air for ventilation, since most units are not designed to heat or cool large proportions of untempered outdoor air
- units located directly in the room or above a ceiling may not meet sound criteria
- space must be allocated from classroom floor space--these units should not be located above ceilings due to maintenance difficulties and potential condensate leakage
- moisture removed from the air must be sent to a disposal point
- wet surfaces in the units may serve as sites for microbial growth, and
- units cannot be equipped with medium efficiency filters.

Induction Systems

Induction systems can handle any size area and allow great flexibility in zoning (either interior or exterior).

Advantages include:

- each area served by an induction unit is a separate zone of temperature control
- systems operate very quietly
- medium efficiency filters can be used
- each zone is guaranteed the proper quantity of outside air (and is measurable)
- ducts may be installed downstream of the induction unit, allowing better distribution within the space, and
- there are no moving parts in the induction unit, and nothing to adjust or maintain except the filter and the heating water control valve or electric coil.

Disadvantages of the induction system include:

- the system concept is relatively new for heating and ventilating application, and many designers are not fully aware of the system's potential, and
- these units cannot provide 100 percent outdoor air

Furnaces

Furnaces (residential type units) serve each classroom. These systems can be natural gas or electric heated.

Advantages of furnaces include:

- each classroom can be individually heated and ventilated
- energy efficient units can be acquired (although life cycle costs must be evaluated to determine if the higher capital costs are offset by reduced energy costs and/or increased service life)
- there is flexibility in locating furnaces--they can be placed in exterior and interior rooms with appropriate outside air connections
- noise can be minimized to meet code requirements through the use of closet-like sound enclosures
- units are relatively inexpensive, and
- medium efficiency filters can be used.

Disadvantages of furnaces include:

- combustion air is required for each natural gas unit
- floor space must be allocated in each classroom for the unit
- air conditioning can be added with a separate coil, however this requires supply and return water piping (or a DX unit) for each furnace, and
- units are not adequate to individually handle large areas, such as a gymnasium. Multiple units are required to serve large areas.

Separate Ventilation Systems[11]

Separate ventilation systems may be used to supplement or upgrade existing systems to current standards. These systems heat, cool, dehumidify, humidify and filter outdoor air in a central system which distributes this air by ductwork to classrooms. They can work in concert with unit ventilators, fan coil units, or heat pumps to overcome some of the shortcomings of those systems. This supplemental ventilation can benefit these existing classroom HVAC units by reducing maintenance, allowing the use of smaller, quieter, and less expensive units, offering better humidity control, reduced condensation on unit cooling coils, and providing cleaner room air at the required ventilation rate.

Facilitating Operation and Maintenance

Designing for good indoor air quality should include measures to simplify access for preventive maintenance, equipment repair, and replacement. Equipment rooms should be sized and designed to facilitate entry, and provide for inspection and servicing of equipment. Ductwork should have access doors to facilitate inspection of dampers, turning vanes, and other components that require periodic inspection, cleaning, or service. Good access should also be provided for inspection and maintenance of filters, condensate pans, heating and cooling coils (and coil housings), and other system components. It is equally important to provide access for maintenance, inspection, and servicing when mechanical equipment is located above ceilings, although locating equipment above ceilings should be avoided whenever possible.[14,15]

HVAC system requirements for operation and maintenance should be realistically matched with the training and capabilities of school district staff, as well as the availability of parts and service. To meet the requirements for good indoor air quality, it is possible that staff knowledge will need to be upgraded and additional training provided. However, an HVAC system should not be strictly selected on the basis of past experience and familiarity, since other concepts may contribute to a more productive and healthy classroom environment.[11]

Another measure which can help reduce repairs and replacement of equipment involves protection of equipment against vandalism. Some units are more easily vandal-proofed than others. Consideration should be given to protection of accessible units, such as unit ventilators placed under windows, and outside air intakes or exhausts.[11]

Relationship with Energy Management

In the 1970s, rising energy prices led to a number of conservation measures which affected the design, construction, and operation of buildings. Because conditioning air became more costly, efforts were made to increase the levels of insulation in walls and ceilings, and to reduce infiltration of outside air by sealing cracks and seams. Thermostats were turned down to reduce energy demand. In addition, ventilation systems usually provided less outdoor air per occupant, with greater recirculation of indoor air which required less energy to heat or cool than outside air.[10]

In recent years, there has been some debate about the impacts of such energy conservation measures on indoor air quality. Essentially, "tight buildings" were blamed for poor indoor air quality, as leaks in the building envelope were sealed. However, the uncontrolled entry of outdoor air is not desirable. Although infiltration may reduce or dilute some air contaminant levels, it is unfiltered and may introduce contaminants into the building, and be a source of drafts and discomfort for building occupants.[10]

As buildings have reduced infiltration and natural ventilation and have come to rely increasingly upon mechanical ventilation systems, it has become clear that proper *operation and maintenance* of such systems is a key component in preventing indoor air quality problems.[10] This is probably even more important now than in the past, since there are new sources of indoor air pollutants which have been introduced into buildings in recent years, and the use of some sources has increased. More recent sources of air contaminants include photocopiers, printers, and other office supplies and equipment.

The greatest compromise with respect to energy management needs and indoor air quality needs is probably related to the supply of outdoor air to building occupants.[10] Mechanical ventilation systems should provide adequate supplies of outdoor air to building occupants--generally 15 cubic feet per person per minute or more, as required by the Washington State Ventilation and Indoor Air Quality Code (Chapter 51-13 WAC) and recommended in ASHRAE Standard 62-1989. However, as discussed earlier, ventilation is only one of many factors which must be considered to prevent and manage indoor air quality problems.

For the most part, energy efficiency objectives and indoor air quality management objectives are compatible, or compliment one another. Good building and HVAC system maintenance can not only help maintain good indoor air quality, but avoid the waste of energy. Here are a few examples:[10,16]

- Poor maintenance of HVAC components such as filters, pulleys, belts, bearings, dampers, and coils can increase resistance and reduce air supply. Good maintenance will improve energy efficiency and indoor air quality.

- Water damage to insulation, ceiling tiles, carpets, and walls nullifies insulating properties and promotes biological growth with the potential for indoor air contamination. Proper maintenance will improve energy efficiency and help prevent indoor air quality problems.

- Reducing infiltration improves comfort and reduces the heating and cooling demands on the HVAC equipment.

A number of actions taken to improve indoor air quality have little or no impact on building energy consumption. Examples include the following:[16]

- Modify janitorial practices and products to eliminate products which produce substantial air emissions, and substitute alternative products where possible.

- Purchase and use building products, furnishings, and equipment which produce lower levels of emissions or have less toxic constituents in comparison to alternative products; and reschedule occupancy or activities to prevent or reduce occupant exposure to contaminants.

- Ensure clean and dry HVAC components, such as drip pans and condensate lines.

There are opportunities in HVAC system design to reduce energy demands. Demand-controlled ventilation may be used. Through the use of a timed program or carbon dioxide controllers, outdoor air flow can be reduced during the times when occupancy is reduced (unless other indoor air pollutant sources require dilution). Energy can also be saved if heat is exchanged from exhaust air to supply air coming into the building. In addition, an important factor to consider in the selection of HVAC components is energy efficiency.[11]

Materials, Interior Finishes, and Furnishings

It is important to evaluate building materials, interior finishes, and furnishings to determine the extent to which they may contribute to indoor air quality problems once the building is occupied. Preferred products can then be specified, procured, and integrated into the building while contributing to a healthy indoor environment.
The process of evaluating building materials can be divided into three steps, which are discussed in detail in this Section:

- identifying materials and products to target
- collecting and reviewing product information and evaluating manufacturers' test results (supplemented with additional testing and modeling as needed), and
- developing recommendations and specifications for product and material acquisition.

Targeting Materials and Products

Most building projects use hundreds of separate materials and products. In selecting materials to target, it is important to consider the overall building design and anticipated uses of space. The intended use of major materials should be reviewed, and the materials that have the greatest potential to adversely affect indoor air quality should be identified for further study. Table 6-3 lists the categories of building materials which are likely to have the most significant impacts on indoor air quality.

There are several criteria that may be used to target materials with respect to indoor air quality concerns. Materials and products may be targeted based upon:[17]

- ***Quantity***--Even products with relatively low emissions per unit area can be important sources of contaminants if used in large quantities. Attention should be focused on products having the largest surface areas or highest total weight per volume of space in a school building. Although threshold quantities have not been established, walls, ceilings, and floor surfaces all have large surface areas, so attention should be directed toward paint, ceiling tile, and flooring systems. Furniture, and built-in cabinets may also have a sizable surface area in a room or building.

Table 6-3: Building Components and Materials to Target for Indoor Air Quality Management[10]

Building Component	**Building Material Targeted**
Site Preparation/Foundations:	• Soil treatment pesticides
Building Envelope (Floors, Walls, Ceilings):	• Wood preservatives • Concrete sealers • Curing agents • Caulking, sealants, glazing compounds, and joint fillers • Insulation, thermal and acoustical • Fire proofing materials
Mechanical Systems:	• Duct Sealants • Duct insulation
Interiors and Finishes:	• Subfloor or underlayment • Floor or carpet adhesives • Carpet backing or pad • Carpet or resilient flooring • Wall coverings • Adhesives • Paints, stains, sealants • Paneling • Partitions • Furnishings • Ceiling tiles

- ***Location***--All other things being equal, students and staff are most likely to be affected by materials that are closest to them. These include work surfaces and other classroom and office furniture.

- ***Human Health Effects***--Some organic chemicals are much more toxic than others. Even very small quantities of certain compounds may cause serious illness or even death. Others may cause DNA damage (including birth defects) and cancer. *Where possible avoid using products which contain highly toxic chemicals, or those containing materials known to cause cancer or birth defects.*

- ***Potential Emission Rates***--Products that serve the same function may have dramatically different emission rates, and may emit different chemicals (the emission factor times the quantity used determines the total emission rate). In addition, emission rates for many materials vary over time, and are influenced by such factors as temperature and humidity.

- ***Contaminant "sink"*** --Some products like carpeting, partitions, and certain furnishings are fleecy and tend to absorb contaminants released from other products, and re-release those contaminants over time. These products may also readily retain dirt, dust, and provide a hospitable environment for microorganisms.

It is important to consider the emissions related to *installation and ongoing use* of each material. The method of installation can be a significant contributor to emissions (for instance, carpet adhesives are a major source of VOCs in carpet installations). The materials that will be used for future maintenance of each product affect its long-term impact on indoor air quality. In the long run, the air emissions of maintenance products may be much more significant than emissions from the original installed product.

Targeting Wet-Applied Materials and Products

The list of target materials should include those that are wet- applied, such as adhesives, paints, caulks, sealants, and finishes. These materials tend to produce high levels of emissions during their application and curing period. Wet-applied materials are of particular concern because such a large portion of their content must evaporate into the air. For many of these materials, manufacturers have reduced the level of solvents, or developed water-based alternatives.

It is important to keep in mind, however, that when high ventilation rates can be used during installation and drying and *occupants are not exposed* to these materials while they are drying, the solvent-based products may be satisfactory. After the products are dry, occupants will be exposed to much lower levels of harmful or odorous chemicals than during the application or curing process.

Latex-based paints typically use water as a vehicle and should therefore be expected to release much lower quantities of VOCs than varnishes and other solvent-based paints. However, there is a great deal of variation among latex and solvent-based paint products with respect to VOC content. It is valuable to examine VOC content in different products before making a selection.[7] It is recommended that architectural coatings containing no more than 250 grams per liter of VOCs be used, where feasible. Some information may be listed on the product container, or may be obtained through Material Safety Data Sheets (MSDSs), suppliers, or manufacturers. Additional information on paint is presented on page 7-10 through 7-12 in Section Seven of this Manual.

VOC emissions from sealants, adhesives, and caulks are difficult to characterize. A large number of different compounds have been found to be emitted from these materials. The composition and intensity of the emissions vary depending on the compound. In large part, these emissions depend on the type of solvent used in the specific formulation for each compound. Similar to paints, emission rates from these materials tend to be highest during the curing period. It is useful to reduce the use of these materials to the minimum quantity needed to perform the job, and provide additional ventilation throughout the application and curing period.[3]

Targeting Insulation

Insulation is useful to target for several reasons. It is a potential site for microbial growth; binding materials or other treatments to the insulation may emit VOCs; and exposed, abraded or deteriorated insulation can shed particles into the air. Fiberglass insulation is also considered a substance "reasonably anticipated to be a carcinogen" by the National Toxicology Program.

Targeting Carpet and Other Fleecy Materials

Fabric upholstery, textile wall coverings, carpets, and other fleecy materials can have a large impact on indoor air quality. Fleecy surfaces act as a "sink" for bacteria, viruses, pollens, spores, organic chemicals, and dust. Dust mite concentrations will also be higher on carpeted floors than hard surface flooring. Dust mite exposure is important in asthma, a widespread disease that is a significant cause of student absenteeism.[17,18]

Consider the advantages and disadvantages of using materials with hard surfaces rather than fleecy surfaces in covering floors, walls, and other interior furnishings. Fleecy materials should be used only when essential for aesthetic or acoustic purposes. They should be installed at a time that avoids peak emissions from other materials, and only with good ventilation to control airborne chemical concentrations.[17,18]

Carpet should not be used in areas of schools that will receive heavy foot traffic, such as entrances and corridors. In these locations, proper carpet maintenance can be too costly and time consuming. Carpet should also not be placed in proximity to water or food sources. In addition, since poorly-maintained carpet may create indoor air quality problems, carpet flooring should only be selected if the school is able to follow the required maintenance program.[17]

Carpeting is a system of components, which usually includes the carpet, pad, adhesive, floor preparation compounds and/or underlayment, and seam sealers. The carpet is typically glued down to a concrete surface that has been prepared with a sealer, or in some cases has a self-adhesive backing.[17]

VOC emissions from carpets are typically small when compared to other components of the carpet system and other building materials. In fact, solvent-based carpet adhesives in glued-down installations represent the most significant source of VOCs in the carpet system. Because of indoor air quality issues, adhesive manufacturers have recently developed low solvent and solvent free adhesives, resulting in low VOC emitting adhesives. Seam sealers are another large source of VOCs, but are usually the least significant by volume among adhesives used in carpet installation. Low emitting compounds are available and should be requested. Carpet pads may also emit VOCs.[17]

It is important to recognize that the volume of emissions from carpet and related materials is important, but even very low emissions (less than 2 parts per billion) of some chemicals (such as 4-phenyl cyclohexane (4-PC) in new carpets) have been associated with illness in certain individuals.

The Carpet and Rug Institute (CRI), a trade organization representing about 95 percent of the industry, has set up a carpet VOC testing program. The CRI test measures total VOCs, styrene, 4-PC and formaldehyde. The organization's testing criteria are set as follows: total VOC emissions should be less than 0.6 milligram per square meter of carpet per hour (mg/m^2/hr), styrene emissions should be less than 0.4 mg/m^2/hr, 4-PC emissions should be less than 0.1 mg/m^2/hr, and formaldehyde emissions should be less than 0.05 mg/m^2/hr. If the carpet passes the test, it is tagged. If carpet for schools is desired, carpet meeting these industry standards (at a minimum) should be specified, although this *does not* guarantee a safe carpet. TVOC testing does not provide information on comfort and health effects of specific VOCs, and there may be significant variations between batches of carpets. Testing the batch to be purchased would provide a more accurate assessment of emissions, although this may be cost prohibitive unless a sizable purchase is contemplated.[17]

Targeting Materials Containing Formaldehyde

School construction frequently uses pressed wood products in a variety of applications. These pressed wood products often contain urea-formaldehyde, a contaminant which may off-gas over a substantial period of time.

Wood products to target include plywood, particleboard, and medium-density fiberboard (MDF). The principle uses of plywood include decorative wall paneling, doors, cabinets, and furniture. Particleboard is used for subflooring, wall paneling, cabinetry (core materials and shelving), cabinet tops, closet shelving, in doors, and furniture. MDF is used in cabinet, furniture, and trim manufacture. Substitutes for these products include composite materials with no urea-formaldehyde; gypsum board for walls; solid wood or metal cabinets; solid wood, metal or plastic furniture; solid wood or metal doors; waferboard, oriented-strand board, iso-board, and phenol-formaldehyde bonded particleboard.[7] *It is recommended that products containing urea-formaldehyde be avoided, or low emitting products be selected.*

Materials can be obtained with lower potential formaldehyde off-gassing (refer to the discussion on the next page concerning collecting and evaluating product information). Researchers have found up to a 23-fold difference in emission from the same products from different manufacturers due to different resins being used and/or pre-treatment to reduce emission levels. Material formulation and pre-treatment can be very effective in controlling formaldehyde emissions.[10]

Barrier coatings and sealants might be used to reduce formaldehyde emissions. Barriers, such as vinyl floor coverings have reduced formaldehyde in residences up to 60 percent. However, caution should be used in selecting sheet vinyl floor coverings, since these coverings have the potential to release high levels of VOCs. Treatment to seal wood products, including particleboard may also be effective. Two to three coats of nitrocellulose-based varnish or water-based polyurethane can reduce formaldehyde emissions significantly. Laminated products should have all surfaces (for instance, the ends of shelves, and unexposed surfaces) covered with laminate. Any pre-drilled holes should be plugged after assembly. It is important to recognize, however, that barrier coatings and sealants may pose their own indoor air quality problems and adequate ventilation should be maintained during application and until the odor fades completely. However, water-based coatings can help reduce VOC emissions.[2,7]

Hardwood plywood or products containing this material should be certified to be in compliance with the Hardwood Plywood Manufacturers' Association Voluntary Standard for Low Emissions (HPMA FE-86) and the U.S. Department of Housing and Urban Development (HUD) Standard 24 Part 3280 (related to the use of pressed wood products in manufactured homes). Particleboard should also meet this HUD Standard and comply with the National Particle Board Association Voluntary Standard for Formaldehyde Emissions (FPA-987).[2]

Targeting Asbestos-Containing Materials

Buildings being remodeled may contain asbestos. Materials of concern in building renovations include roofing felts, roofing cements, concrete additives, coal tar pitch, vermiculite, vinyl asbestos tiles, plaster, gypsum board, stage curtains, ceiling tiles, and spray texture.[2] Management of asbestos in buildings is discussed further on pages 9-6 through 9-8 of this Manual.

Collecting and Evaluating Material and Product Information

Building materials known to have low pollutant emission and toxicity characteristics should be preferred. When these are not available, products with higher emission levels may be used provided that contamination of building air is minimized by temporary ventilation, off-site curing, and/or isolation of such materials from the interior environment.[1]

In communicating with materials suppliers, designers should clearly express their concerns about maintaining good indoor air quality. *An emphasis should be placed on the manufacturers to test products and make the results available to the design team.* Standardized test procedures are evolving, and many manufacturers are becoming accustomed to requests or bid document requirements that they submit information concerning product emissions.

School designers should ask manufacturers for information on material content, including the presence of carcinogens or reproductive toxins, and the compliance of the product with specific emission rate guidelines (see page 6-40). Information should also be requested concerning the emission test protocol, and organization evaluating the product. When considering products such as carpeting, it is useful to obtain similar information on the products necessary for proper maintenance. As noted above, the CRI testing program can be one screen for carpet product selection.

Representative samples of prospective finishing materials may be acquired. Samples should be stored in a closed jar to determine if odors are generally unacceptable either by laboratory analysis or sniff test using a representative sample of staff and students.[8]

MSDSs should be reviewed for materials that vendors may use when installing finishing materials, particularly adhesives or solvents.[8] When insufficient information is available from the MSDSs, suppliers or manufacturers should be contacted. If this is not practical or possible, an alternative product whose contents and safety are known and acceptable may be a better choice.

Product information for building materials, supplies, furnishings, and other products is available through a number of sources. For instance, *Environment by Design: A Sourcebook of Environmentally Aware Material Choices* by Kim LeClair and David Rosseau identifies building products which may have lower environmental and public health impacts. Caution should be used in reviewing alternative products, to determine the merits of claims by manufacturers concerning product emissions, and independent testing to substantiate claims.

EPA has also completed a catalog which categorizes materials and identifies their potential to impact indoor air quality. This document is available from the National Technical Information Service (NTIS) as EPA 600/8-90-074, *Classification of Materials as Potential Sources of Indoor Air Pollution.*

Emission rate tests may be conducted using the dynamic environmental chamber technology as prescribed by the U.S. Environmental Protection Agency (EPA-600/8-89-074). As an alternative, materials may be tested in accordance with ASTM D5116-90, Small Scale Environmental Determination of Organic Emissions from Indoor Materials/Products.[4,6]

It is important to review and evaluate manufacturers' test results. Even when emission test data are available from manufacturers, batch-to-batch variations in formulations, variations in manufacturing processes, curing, packaging, storage, transport, and other factors limit its usefulness. Because of variations in product emissions from test data, pre-conditioning and building flush-out (discussed later in this Section) provide an additional opportunity to reduce emissions before students and staff occupy the building.

Specifications for Targeted Materials

Based upon the designer's evaluation of relevant product information, it is then possible to develop recommendations and specifications for targeted materials. As discussed above, it is appropriate to place responsibility on the product manufacturer to provide data on product emissions. For most products of concern, designers should include the following in their product specifications: 1) a clear identification of the school district's objectives for indoor air quality management, and *specific emission* *limits or restrictions* regarding chemical content of products; and 2) a requirement for submission of product *chemical contents and emissions test results* to demonstrate that the manufacturer has investigated the product's performance. Documentation should be provided which indicates that the product meets the school district's requirements.

Test data of emission rates or source strengths of building products and materials are also useful when 1) prescribing ventilation system operating protocols to maintain acceptable indoor air quality, and 2) when assessing complaints associated with indoor air quality problems. For instance, it is possible to select materials with fast decay curves, use increased ventilation to further accelerate the decay process, and delay the installation of carpeting or other fleecy materials until after the bulk of VOCs have been emitted from the materials and removed from the building. Information on emission rates and decay curves can also be useful in negotiating with manufacturers and suppliers to minimize VOCs through *pre-shipment storage practices* and *modified installation procedures*.

Emission Rate Guidelines

Following are emission rate guidelines which are adapted from those used by the Washington State Department of General Administration in selecting targeted building materials for state office buildings. These guidelines are discretionary, and are being provided to help school districts formulate guidelines for their own use to obtain products with lower emissions in new school construction and school remodeling projects.

The specifications should require the contractor to provide written notification to all suppliers of materials of concern, to assure that product emission procurement specifications are met by the manufacturers. A compliance form may be used to require certification of compliance from manufacturers or suppliers.

All emission rate calculations should specify the occupant space volume to determine product loading. An average school classroom, for instance, may provide approximately 300 cubic feet (8.5 cubic meters) of space per person. (This example is based upon the assumption that the classroom is 1000 square feet in area, nine feet high, with up to 30 occupants.):

Formaldehyde Emission Rates: The product emission rate measured in milligram per square meter of emitting surface per hour (mg/m^2/hr) should not result in an indoor air concentration level of formaldehyde greater than 0.05 ppm at the anticipated loading (square meters of floor space per cubic meter of occupant space (m^2/m^3)) within 30 days of installation.[6]

Total Volatile Organic Compound (TVOC) Emission Rates: The product emission rate in mg/m^2 per hour should not result in an indoor air concentration level of TVOCs greater than 0.5 mg/m^3 at the anticipated loading (m^2/m^3 within the building) within 30 days of installation.[6]

4-Phenyl Cyclohexane (4-PC) Emission Rates: The product emission rate in mg/m^2 per hour should not result in an indoor air concentration level greater than 1 part per billion (ppb) of 4-PC at the anticipated loading (m^2/m^3 within the building) within 30 days of installation.[6]

Other Pollutant Emission Rates: Any pollutant not specifically mentioned in the three paragraphs above should meet an emission rate standard that will not produce an air concentration level greater than 1/10 the Threshold Limit Value (TLV) industrial workplace standard (Reference: American Conference of Governmental Industrial Hygienists, 1330 Kemper Meadow Drive, Cincinnati, Ohio 45240) at the anticipated loading in the building within 30 days of installation.[6]

Conditioning of Furnishings and Materials

Pre-conditioning of building materials and products allows off-gassing and ventilation of emissions prior to installation. If materials are pre-conditioned, they may be more likely to meet product emission standards established in the specifications. In addition, pre-conditioning may allow a reduction in time set aside for air flushing (before building occupancy) once the product is installed.

The appropriate type of pretreatment depends upon the type of material, budget available, and flush-out time available in the building. For instance, vinyl-impregnated flooring might be subjected to a factory bake-out, and furniture or carpet might be unwrapped and unrolled in a ventilated warehouse until airborne pollutants are dissipated as much as possible, before installation in the building.[1]

Suppliers may be able to unpack, unwrap, and store new dry furnishings and materials (such as carpet and other flooring materials, acoustic tiles, other textiles, office furniture, and wood shelving) in a clean, dry, ventilated location for at least 24 to 48 hours so that some volatile organic compounds will be emitted before installation.[4,9,17]

Recommendations for Cancer-Causing Agents and Reproductive Toxins

It is useful for each school district to be aware of any building products, materials, furnishings, or finishes which may contain cancer-causing agents or reproductive toxins. This information can assist the district in identifying the level of risk, and selecting alternative products where appropriate. *Where possible, use of these products should be avoided, or if required, occupant exposure should be prevented or minimized.* Building contractors and suppliers should be required to disclose in writing any detectable amounts of carcinogens (substances which are proven to cause cancer), mutagens (substances which are proven to alter DNA), or teratogens (substances which are proven to cause birth defects) which are likely to be emitted into the indoor air from any materials, furnishings and finishes they propose to install. The following resources may be used to identify such agents and toxins:[4]

- *IARC Monographs on the Evaluation of Carcinogenic Risks to Humans* by International Agency for Research on Cancer, 1987, or most recent revision

- *Sixth Annual Report on Carcinogens* by US Dept. of Health and Human Services, 1991, or most recent revision, and

- *Catalog of Teratogenic Agents*, Sixth Edition by Thomas H. Shepard, or most recent revision.

Controlled Application of Wet Materials

During construction, the following procedures should be followed to minimize and control the emissions from wet construction materials. The smallest feasible quantity of VOC-emitting wet materials, such as adhesives, paints, sealants, glazes, and caulks should be used during construction and applications. Control strategies for achieving minimal use of wet materials should be discussed with the school district or its representative for prior approval before such wet materials are used.[4]

Dry materials such as carpet, acoustical panels, and textiles, may serve as a sink for indoor air contaminants, absorbing them and releasing them over an extended period of time. To minimize absorption and extended release of contaminants, dry furnishings should not be installed until wet materials (such as paints) have been applied and allowed to dry, where possible. Drying times should be chosen so pollutant emission rates, as set forth above, are achieved before installation of dry furnishing materials.[4]

Air Flushing before Occupancy

To reduce or flush out indoor air contaminants *prior to occupancy* in newly constructed or remodeled buildings, ventilation with 100 percent outdoor air should be provided at normal operating temperatures. Air flushing will help remove VOCs, and improve the quality of the air the occupants receive once they arrive at the building.

Careful attention during the facility planning stages should be given to scheduling for air flushing. School districts should consult with the design team and allow as much time as reasonably possible for air flushing before occupancy. In some buildings owned by the State of Washington, a total of 60 to 90 days was allowed for air flushing. It is recognized that air flushing for two to three months may not be feasible for school districts, especially following school remodeling projects. In addition, there is not adequate documentation to show the extent to which 60 or 90 days of air flushing is more beneficial than flushing for a shorter time period, such as 14 to 30 days.

However, school districts should schedule some air flushing before occupancy, and should not *immediately* move in students and staff after construction and furniture placement. One option that may be considered is to schedule part of the air flushing period during the two-to-three week cleanup period at the end of construction. If air flushing is conducted during cleanup, additional filtration will be needed to handle excessive amounts of dust resulting from construction activities.

If the desired level of air flushing before occupancy cannot be achieved, emphasis may need to be placed on other methods to reduce staff and student exposure to VOCs. More attention may be placed on materials selection, pre-conditioning of materials, and supplemental ventilation following occupancy.

It is recommended that where possible, air flushing occur in two stages. The first stage of air flushing should take place after completion of all interior construction and *prior* to placement of any furniture in ventilated spaces. The second stage begins after all furniture has been unpacked and placed in the ventilated space. The project should not be considered substantially completed until the agreed upon flush-out period has been completed. The designer/builder is encouraged to operate all air handler systems on

100 percent outside air as much as possible beyond the designated flush-out period before building occupancy.[4,6]

It is also desirable to schedule the flush-out period during the summer months, if possible. This will help minimize excessive energy consumption.[6]

As the building is ventilated, the doors and drawers of cabinetry and furnishings should be opened for full exposure. All cabinetry should be inspected for surfaces of exposed particle board; a source of formaldehyde emissions. If found, these surfaces may be treated with two or three coats of nitrocellulose or water-based polyurethane lacquer.

Bake-Outs before Occupancy

"Bake-outs" are recommended by some indoor air quality agencies and specialists as part of the commissioning process to control VOC contaminants in new construction.

Bake-outs are based on the theory that elevating temperatures in the building increases the vapor pressure of residual solvents in building materials, and if maintained long enough, will cause the depletion of solvents, with a corresponding reduction in VOC emissions.[7]

However, the results of bake-outs are inconclusive, based on studies to date. Some research shows reduced levels of VOCs as a result of bake-out, while other research shows about the same level of VOCs after a bake-out as before.[10]

Some indoor air quality professionals have expressed concern that bake-outs may damage some building materials and components.

Currently, data supporting the effectiveness of building bake-outs are inconclusive. Because the results are inconclusive, flushing of the building as part of the start-up for new buildings is preferred.

Design Documentation

From the outset of a project, thorough documentation improves communication among members of the design team and between the designers and clients, construction contractors, and building operators. Design documentation for HVAC systems is essential, and called for under ASHRAE Standard 62-1989. It is desirable to designate a member of the design team as the lead person and contact for project documentation issues.

Documentation should include the pollutant source control plan, site planning considerations with respect to maintenance of indoor air quality, and specific HVAC design elements, including design objectives, system performance assumptions, loads, control logic, and other aspects of the HVAC system and its operation. Decisions regarding the selection, testing, pre-conditioning, installation, and pre-occupancy ventilation of materials, interior finishes, and furnishings should be documented.

Documentation is also valuable for training operation and maintenance staff and can be useful in resolving occupant complaints. It may also help reduce liability in the event of litigation if the documentation establishes the designers' and school district's efforts to produce and maintain good indoor air quality.

As project documentation accumulates, it may be useful to organize and assemble it in durable, moisture-resistant binders. Supplemented by operating and maintenance recommendations, the documentation helps to create an owner's manual for the building. Architects and engineers should retain copies of the project documentation in their files and distribute multiple copies to building owners and operator.

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Section Seven: Constructing Schools for Good Indoor Air Quality

Introduction

Section Seven discusses elements of school *construction* which are important in assuring good indoor air quality once the building is occupied. These elements include monitoring of construction activities, review of construction change orders, and building commissioning. Section Seven also recommends HVAC system maintenance staff training as construction is completed, and addresses the need for documentation of construction and commissioning tasks.

Since some construction, remodeling or renovation projects will occur while the building is occupied, precautions should be taken before, during and following completion of these projects to protect students and staff from unnecessary exposure to indoor air contaminants. The precautions which should be followed (at a minimum) in these remodeling activities are listed. In addition, three types of building improvements which have the potential to create indoor air quality problems are discussed: painting, carpeting, and roofing projects.

Note: The practices specified or recommended in this Manual include some that are already required by code or law, and others that are recommendations which may help promote good indoor air quality in schools. It is the responsibility of each school district and other users of the Manual to comply with applicable codes and laws--including those related to building, plumbing, electrical and mechanical systems, fire protection, safety, energy use, and environmental protection. However, all users of the Manual, including school districts, should evaluate the discretionary recommendations presented in this Manual, and adopt or promote those which, in their judgment, are relevant and applicable to their circumstances, and feasible to implement. In the event that any recommendations offered in this Manual are in conflict with any applicable codes or laws, such codes or laws shall take precedence. Note that some of the recommended *activities are in addition to those customarily performed by outside consultants or in-house staff providing design or related professional services for school districts.*

Monitoring Construction

During construction, it is essential that the design objectives and requirements intended to maintain good indoor air quality are followed. Adherence to indoor air quality performance goals and criteria should be monitored during all field visits and progress inspections. To accomplish this, the school district's IAQ coordinator, or the architect and engineer should be requested to

identify critical components to be monitored during construction, and develop a plan for construction site monitoring or quality control related to indoor air.

For instance, where possible, air supply and return system testing, adjusting, and balancing work should be monitored and verified as the work is progressing. Products selected for building construction and finishing should also be verified, as well as installation practices and sequences for installation. In addition, a review of work area cleanliness should be undertaken, since dirt and debris accumulation in the HVAC system can present indoor air quality problems. Project specifications should clearly define the requirements for specific products, workplans, and desired practices and installation sequences to help ensure good indoor air quality.

Construction Change Orders

Changes made by contractors or designers during construction can significantly affect indoor air quality. These changes are often in response to previously unanticipated problems or events during construction. During the change order and shop drawing approval process, architects and engineers should assure that any changes meet the design intent and indoor air quality performance criteria that have been established. It is especially important to carefully review modifications and substitutions of HVAC system components, sealants, finishes, insulation, composite wood products, furnishings, and other items that the designer has identified as important for indoor air quality.

The Commissioning Process

Verifying Building System Performance

Commissioning involves verifying the performance of building systems to assure that building systems meet the design intent and satisfy the needs of the school district and building occupants. Building systems may include the HVAC system, the building envelope and structure, the electrical and lighting system, the plumbing system, and fire protection system. Of principal concern with respect to indoor air quality is commissioning of the HVAC system. The reader is referred to ASHRAE Guideline 1-1989, *Guideline for Commissioning of HVAC Systems* for detailed information. The final product of HVAC commissioning is a functional, finely-tuned system for heating, ventilating, and air conditioning the building. Recommissioning may be necessary in
the future to address changes in space use and occupancy, and deterioration of HVAC performance with age.

HVAC commissioning begins at the pre-design stage, not after construction. At this early stage, the roles of the design and construction teams in commissioning are defined, building requirements are outlined, and minimum requirements for the HVAC system are defined for the school. This should include defining HVAC needs and layouts for each area of the school and activity, with consideration given to occupancy levels.[1]

HVAC design documents should include requirements for a *commissioning plan*. The commissioning plan is customized for each project, describing the commissioning process from start to finish. It should be completed before the construction phase of a project. The plan should state the requirements that each party involved in commissioning should follow, including the sequence for commissioning tasks, scheduling of tasks, documentation requirements, verification procedures, and staffing needs.[1,2]

It is important to make sure that commissioning tasks are incorporated into the contract specifications. The specifications should define responsibilities of the parties in all phases of the project; describe the commissioning process through the project phases; and state requirements for performance tests and checklists, for preparation of operation and maintenance manuals, and for operation and maintenance training, and documentation.[2]

The commissioning agent normally takes a lead role in preparing a commissioning plan, test plans, and reports. This person may be assigned from the school district, or may be an engineer hired to perform this function (although not necessarily from the design team). The agent also coordinates the commissioning team and work schedule, reviews commissioning specifications, oversees performance tests, and reviews training materials, procedures, operation and maintenance manuals, drawings and other documentation. Other parties involved in commissioning have different, but complementary roles. For instance, contractors may perform tests and checks of components and systems, adjust equipment and systems, assemble operations and maintenance manuals, and help train building staff.[2]

The commissioning agent may also perform the role of IAQ coordinator, depending upon the individual's expertise and the preferences of the school district. The duties of the IAQ coordinator were outlined on pages 4-4 and 4-5.

Performance Testing and Inspections

Without proper commissioning, testing, and balancing, buildings are likely to be delivered to the owner and operating staff with many operational problems remaining. To know that the building is operating as designed, the performance and operation of the systems should be verified through functional performance testing. Functional performance testing should progress from equipment or components through subsystems to complete systems. At the end of the process, all systems and equipment must be shown to be operational under all normal and emergency conditions. Each system should be operated through all modes of system operation, including seasonal, occupied and unoccupied, or warm-up and cool down, as applicable. These tests, along with other tasks in the commissioning process, help eliminate problems by identifying and correcting deficiencies early in the construction process. Prior to functional performance testing, the commissioning agent should observe and verify that the system is physically installed in accordance with the contract documents.[1,2]

The commissioning plan should define the detailed procedures for testing by each party. It should include a checklist for performance testing, report forms to submit test data, and it should state calibration requirements for test equipment. A sequence and schedule for completion of all testing and related procedures should be outlined.[1]

Building Performance

As part of commissioning, *building performance* should be tested before occupancy. This includes a thorough test of the building envelope to ensure there are no water leaks, that doors and windows are correctly sealed and operate as intended, that drains are functional, and that outdoor air is not being drawn into the building through openings in the envelope (doors and windows) located near loading docks or other potential problem areas. Mechanical systems should be checked to verify that they operate correctly, that systems are balanced, and that outdoor air dampers operate correctly. The HVAC system should be checked to be sure that the proper amount of outdoor air is distributed to interior spaces, that all air supply registers, diffusers, and return grilles are open and unobstructed, and that they provide for adequate mixing in each supply zone. Local exhaust grilles and hoods should be inspected and tested to verify proper installation and operation. Appropriate negative and positive pressure relationships should be verified in all interior zones.

Air Quality Monitoring

School districts may wish to institute an *air quality monitoring program* before the building is occupied. Monitoring can be used to develop baseline data before occupancy to show changes over time; detect unusual levels of common compounds; look for compounds of concern that were identified during the selection of building materials; and to detect the presence of radon or other soil gases. This information can be used either as a basis for taking corrective actions or to verify that the building HVAC system is functioning properly. Tests may include measurement of VOCs, carbon monoxide, carbon dioxide, radon, and total particulates.

Maintenance Staff Training

It is useful for the building operations and maintenance staff to be on site periodically during construction, particularly during startup, testing, adjustment, balancing, and performance testing. This will help familiarize operators with equipment, components, and systems. To the extent possible, these activities should be scheduled in advance so that building staff may make arrangements to attend.[1]

Building operators should be provided with complete training in operation and maintenance of the HVAC system. This may be provided by specialized contractors and/or manufacturers' representatives. Training should include:[2]

- overview of indoor air quality issues and their importance
- equipment startup procedures
- operation in normal and emergency modes

- shutdown procedures
- seasonal changeovers
- a description of all equipment and systems
- warranties and guarantees
- requirements and schedules for all maintenance
- health and safety issues
- special tools needed and spare parts needed in inventory
- operation of dampers, valves, and other manual and automatic controls
- troubleshooting problems
- identification of information which may be found in the operating manuals, and
- locations of all HVAC system plans, documents, and manuals in the facility.

Documentation Requirements

Documentation is essential in all phases of building design and construction--from the early pre-design stages through commissioning following construction. At the pre-design stage, it is useful to document design and benchmark information, including occupancy requirements, design assumptions, building construction, building loads, zoning, cost considerations, building uses, and design compromises.[1]

Few, if any buildings are constructed precisely as they were designed. Documentation during construction, commissioning, and initial occupancy should record the progress of the project, departures from the original design (reflected in as-built drawings), and any events that might be expected to affect indoor air quality in the completed building. It should also include test and balance reports and other test results from the pre-occupancy and post-occupancy period.

Each check or test should be documented. A copy of the HVAC commissioning plan and functional performance test results should be included with the operation and maintenance manuals.[1]

Documentation of building and HVAC system performance may be accomplished in part through video taping. This form of documentation may be especially useful in providing training to operation and maintenance staff.

A useful reference for documentation is ASHRAE Guideline 4-1993, *Preparation of Operating and Maintenance Documentation for Building Systems*. It complements ASHRAE Guideline 1-1989, *Commissioning of HVAC Systems*.

Responsibility for documentation should be determined and assigned for each work component as early as possible. Documentation may be required of the IAQ coordinator, commissioning agent, other district staff, architects and engineers, and contractors. Documentation should be kept on file at the school district's central offices. Additional copies of applicable information may also be kept in the school's files.

Ventilation Protocols during Initial Occupancy

As described on page 6-43 of this Manual, flushing a building with 100 percent outdoor air is recommended before occupancy. *After the building is occupied*, it is advisable to continue flushing out air contaminants with additional ventilation. This may be accomplished by operating the ventilation system at normal rates seven days per week, 24 hours per day for a designated period following occupancy. The State of Washington has required extended flushing after occupancy of some new state buildings for up to 90 days.[3] As an alternative, it may be desirable to extend the lead time for operation of the HVAC system prior to building occupancy each day. Extending the lead time will help flush out contaminants which have accumulated in the building air overnight.

Remodeling or Renovation

The following guidelines are designed to help maintain good indoor air quality while remodeling or renovating existing school facilities. *Remodeling or renovation* refer to activities including removal and/or replacement of:[4]

- roofs, walls, ceilings, lighting, HVAC systems, plumbing, sewers, floors, or floor coverings

- architectural coatings such as paints, and

- built-in furnishings.

As a first step, it is useful to define the project's goals with respect to indoor air quality. Procedures, schedules, construction methods and materials, and building systems operations should be controlled to prevent or minimize degradation of indoor air quality as a result of remodeling or renovation.[4]

Goals

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HVAC Changes

It is important to keep in mind that remodeling may involve *changes* to the HVAC system, or it may *affect* the way air is distributed by or returned to the HVAC system. Examples include changes in ductwork, or construction of walls that separate air supplies from returns, or that separate temperature zones. Where such changes are made, make sure that affected areas are provided with appropriate ventilation at levels specified by the ventilation code and ASHRAE Standard 62-1989, that the air is distributed efficiently, and that the zoning is proper.[4]

Preparing a Work Plan

Before remodeling or renovation activities are started, the school facilities or project manager should meet with the contractor or individual(s) selected to perform the work to develop a written work plan (note: requirements for a work plan should be clearly identified in the project specifications). This work plan should be designed to prevent or minimize the introduction of air contaminants to occupied areas during and after the work, and should reflect all guidelines outlined in this section.[4]

Notification and Scheduling

When possible, remodeling in an occupied or partially occupied building should occur when occupancy is at *its lowest levels.* Depending upon the nature and extent of remodeling, it may also be possible to temporarily relocate students and staff who are most likely to be affected by remodeling activities. These actions can help reduce the exposure of students and staff to noise as well as indoor air contaminants. Care should be taken to provide additional ventilation during unoccupied periods, since HVAC system controls typically reduce or eliminate outdoor air ventilation at these times.

School administrators should notify building occupants, including teachers, administrative staff, maintenance staff, students, and parents in advance of remodeling work to be performed. At a minimum, it would be desirable to provide at least three days notice for scheduled work, or twenty-four hours notice (if possible) for emergency work. The notice should briefly describe how indoor air quality and other school health and safety conditions may be affected by the work, and what actions the school and the contractors will take to eliminate or reduce the exposure of building occupants to noise and pollutants.[4]

Ventilation Control and Work Area Isolation

Like other construction activities, remodeling and renovation may produce gases, vapors, dust, and other indoor air contaminants. Measures should be taken to adequately ventilate work areas while minimizing the release of indoor air contaminants to other areas of the building. This can be accomplished by restricting air flows from the work area, providing supplemental or auxiliary work area ventilation, and using pressure containment (keeping the work area at a negative pressure with respect to the occupied areas).[4]

Examples of ventilation controls include blocking off or sealing return air registers so that contaminants are not drawn from the demolition/construction area and recirculated into adjoining occupied areas; installing temporary barriers to confine dust and noise; and setting up temporary local exhaust fans to remove odors and contaminants. Caution should be used to avoid the exhaust of contaminated air near outside air intakes.

If necessary, fumes, dust, gas, and vapor suppression and/or auxiliary air filtration or cleaning may be used to control the release of contaminants. Care should be taken to inspect, clean and replace air filters during and after remodeling or renovation, since additional dust and other contaminants are generated.[4]

Asbestos Exposure

Some renovation or remodeling may expose asbestos-containing materials. WAC 296-62-077 governs remodeling activities where employee exposures to asbestos could occur.[4]

Selection of Material, Interior Finishes, and Furnishings

In undertaking building renovation or remodeling, it is important to take precautions in selecting and installing materials, finishes and furnishings to minimize the introduction of indoor air pollutants. It is suggested that the recommendations for selection and application of materials, and ventilation procedures defined for new construction (page 6-32 through 6-45) be reviewed and, where feasible and applicable, be used in the remodeling or renovation process. This includes targeting products, collecting and evaluating information on potential air emissions and other hazards associated with products, identifying and specifying acceptable emission rates to minimize occupant exposure to indoor air contaminants, and taking other reasonable measures to pre-condition products or ventilate buildings during and following application or installation.[4]

Painting Projects

In conducting a painting project in an occupied or partially-occupied building, it is useful to consider the recommendations offered on pages 6-32 through 6-45 of this Manual concerning the selection and application of materials, interior finishes, and furnishings, and specifically recommendations for targeting wet-applied materials (page 6-34 and 6-35).

Paint formulations are often complex mixtures. They have the potential to introduce a multitude of chemicals into the indoor air. Other products such as strippers, primers, and thinners are also used in painting projects. All of these products can produce solvent odors, which can cause discomfort and health symptoms in people exposed to these products during application, and during the period of evaporation after application. Paint pigments may contain lead and other metals.[5]

Many paint strippers have contained methylene chloride, a toxic chemical and suspected carcinogen. New strippers are on the market which do not contain this chemical and claim to emit low levels of VOCs.[5]

The two primary types of interior paints are alkyd or solvent-based paint, and latex paint. Solvent-based paint has a higher VOC content, typically ranging from 300 to 400 grams per liter, while latex paint has between 50 to 250 grams of VOCs per liter.[5] VOC content is specified on most paint containers in response to disclosure requirements imposed by the State of California. VOC content is listed on containers in milligrams per liter.

Although paints with low VOC content may be desirable, some of these paints have drawbacks: they may be more difficult to apply, may require additional coats, may be more susceptible to fading, may be less resistant to mildew, less washable, and may be more costly.[5]

Durability is also important. A paint with lower VOCs might create more indoor air quality problems in the long run than a higher emitting paint, if the low-emitting paint requires repainting more often[6].

Select paint that is rated for the surface to be painted. Interior paints sold before September 30, 1991 may contain mercury, and therefore should not be used. Exterior paints should not be used for interior use since this could also lead to exposure to biocides and mercury. In addition to considering VOC emission data on the container, it is useful to obtain MSDSs on the paints under consideration. After reviewing available information, select the paint and related paint products that have the lowest hazard potential while providing good functional qualities, within the limits of the budget[5].

Good management of paint projects can minimize indoor air quality problems. One method of control is the use of a paint protocol which gives proper notice to the school administration, parents, students, and minimizes exposure. The Anne Arundel Public Schools have developed a model paint protocol, which is presented in their document *Indoor Air Quality Management*, and in the EPA document *Indoor Air Quality Tools for Schools*.[6,7]

Before painting, a proactive effort must be made to communicate with all affected parties. This means letting teachers, staff, students, and parents know what painting will be done, how it will affect students' schedules, and steps the school will take to reduce impacts. Work should be scheduled during unoccupied periods or low occupancy, if possible[5].

Project specifications should require a work plan that considers the need for paint removal and how that will take place. Off-site paint removal of some items (doors, windows, trim) may be appropriate. Special care should be taken when sanding a surface to prepare for painting, due to the dust released into the air. Dust from older paint may also contain lead particles, although paints manufactured after February 1978 had reduced lead levels. Methods to deal with lead paint vary, depending on the status of the facility. Control can range from simple encapsulation to total removal depending upon the severity of the condition. The painted surface should be determined to be lead free before preparing for repainting. This can be confirmed by checking paint records or old paint cans, or performing an initial screening with the assistance of trained personnel.[5,6,7]

The work plan should also provide for protection of furniture, supplies, and other articles in the work area. These articles may absorb vapors and slowly release them back to the room air after reoccupancy.[5]

Areas should be well ventilated during painting and for several days after painting. Supply fans should be operated continuously from the beginning of the painting project until several days after the painting is done. It is useful to block return air openings to prevent circulating air from the work area to occupied areas.[5,6]

Some items may be painted in a protected area outdoors, or in a well-ventilated area offsite. Paints may be mixed in a protected outdoor area as well. Paints and products such as thinners and cleanup materials should be in closed containers when not in use. When paint is poured, for instance, the lid should be placed back on the container. Paint and related product containers should be sealed after use. Containers should also be stored in designated rooms equipped with exhaust ventilation--never in HVAC rooms, where vapors from containers or spills could enter the HVAC system. Some paint products, including existing stocks containing lead or mercury, or having higher VOC emission than desired will require proper disposal or recycling. The local health department or solid waste utility should be contacted for information on proper disposal of paint products, materials, and cleanup supplies.[5,6,7]

Carpeting Projects

For carpet selection and installation in occupied buildings, it is useful to follow the guidance concerning selection, use and installation of materials, interior finishes, and furnishings on pages 6-32 to 6-45 of this Manual, and specific recommendations on pages 6-35 and 6-36 concerning carpet and other fleecy materials.

A decision may be made to replace an existing tile floor with carpeting. In this case, it is important to determine whether the old tile flooring contains asbestos fibers. Information may be found in inspection reports under AHERA surveys and management plans on file at the school.[6] Careful consideration should be given to the costs and indoor air impacts associated with removal of asbestos tiles versus leaving the tiles in place. Removal of asbestos-containing products may present greater costs and health risks to workers, school staff, and students than a project in which asbestos-containing products are adequately contained, but left in place.

Additional ventilation should be provided after new carpet installation. If possible, continuously operate the building ventilation system at normal temperature and maximum outdoor air during installation and for 72 hours after installation. It is advisable to install carpet only when the building is not in use, except in small areas where direct exhaust under negative air pressure (in relation to surrounding rooms and hallways) may be applied. New carpet should be cleaned with a HEPA filtration vacuum.[6]

Roofing Projects

Roofs should be maintained to avoid ponding of water, and roof leaks and internal water-damaged materials should be dried or replaced in a timely fashion. If possible, roof replacements should introduce a slope to an existing flat roof system. Flat roofs collect water, and after leaks appear, require patching or replacement which sometimes involves the use of adhesives or tars. These materials often contain toxins which may be harmful if their fumes enter the building.[7]

If possible, roofing projects should be undertaken when the school is unoccupied since vapors may enter air intakes. Roofing tar tanks (instead of open kettles) should be located as far away from air intakes as possible, and preferably downwind from the building. If this is not feasible, consideration may be given to temporarily blocking nearby air intakes, or shutting down the HVAC system and allowing natural ventilation while supplementing the air supply with portable fans.[7]

A school developing plans to replace or repair or construct a flat roof should ensure that the *specifications* clearly require the contractor to remove all failed materials, and take precautions (recommended above) to ensure that fumes from the installation of build-up materials or membranes cannot be drawn into or infiltrate the school.[7]

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Section Eight: Operating and Maintaining HVAC Systems for Good Indoor Air Quality

Introduction

Section Eight discusses measures that should be taken to keep the building's heating, ventilating, and air conditioning system maintained and operating properly. Responsibilities that should be assigned to staff to maintain HVAC systems and good indoor air quality are summarized. Documentation needs are discussed, since documentation provides a foundation for a preventive maintenance program and associated personnel training. Documentation also helps ensure proper operation of systems, and can assist in resolving indoor air quality problems and complaints. General maintenance standards for HVAC systems are also described.

Note: The practices specified or recommended in this Manual include some that are already required by code or law, and others that are recommendations which may help promote good indoor air quality in schools. It is the responsibility of each school district and other users of the Manual to comply with applicable codes and laws--including those related to building, plumbing, electrical and mechanical systems, fire protection, safety, energy use, and environmental protection. However, all users of the Manual, including school districts, should evaluate the discretionary recommendations presented in this Manual, and adopt or promote those which, in their judgment, are relevant and applicable to their circumstances, and feasible to implement. In the event that any recommendations offered in this Manual are in conflict with any applicable codes or laws, such codes or laws shall take precedence.

Assignment of Responsibilities

No matter how good the design and construction of the school HVAC system, it will not perform its functions well without proper operation and maintenance. School districts should assure that properly trained personnel are assigned and available to perform

HVAC maintenance. A written list of responsibilities for the HVAC maintenance staff should be prepared.

School administrators should also make certain that school activities or operations do not adversely affect the quality of the indoor air. Many of the practices recommended in this Manual are intended to help prevent indoor air quality problems from activities such as cleaning and maintenance, as well as building repairs and school classroom functions. In addition, school district administrators should ensure that all records pertaining to the operation and maintenance of the HVAC system are properly maintained.[1]

The HVAC maintenance personnel should document the completion of all assigned maintenance, and in the event of an indoor air quality problem, should work with school administrators, other staff, and any outside consultants selected to assist in problem resolution.[1]

Documentation

School districts should maintain a file containing the following written description of the HVAC system installed in each building[2]:

- the type of HVAC system (for instance, unit ventilator, variable air volume, single zone)

- a sketch or narrative describing HVAC zones and what equipment serves each zone. Design documents or blueprints may be made available for this purpose

- HVAC system components, delivery system, and controls

- types of activities and uses within each area of the building, and

- mechanical systems used for local exhaust.

School districts should also maintain the following to assist in conducting indoor air quality evaluations which may be needed[2]:

- HVAC system designs and assumptions
- bid documents

- building permits
- certificate of occupancy
- commissioning reports
- as-built drawings
- air balancing reports, and
- photos and videotapes (if available).

HVAC operations and maintenance guidance should be readily available to HVAC operation personnel. The guidance should include manufacturers'recommended procedures and timelines for maintenance of HVAC systems components. To the extent that such information is not available, guidance should be obtained from knowledgeable professional organizations or contractors.[2]

Maintenance Standards

Personnel operating HVAC systems should rely upon the operation and maintenance guidance prepared specifically for the school building and use the information presented here to supplement existing guidance. A useful reference document for HVAC maintenance is *Building Air Quality*, prepared by EPA, the U.S. Department of Health and Human Services, the Public Health Service, Centers for Disease Control, and the National Institute for Occupational Safety and Health.[3]

The following recommendations are intended as a broad overview of maintenance guidance associated with HVAC systems.

Inspection and Maintenance of HVAC Systems and Components

It is critical that HVAC components be inspected, adjusted, cleaned, calibrated, or replaced as specified in the maintenance guidance. Components requiring attention include, but are not limited to air filters and filter seals, condensate pans and drainage piping, heating and cooling coils, supply and exhaust vents and louvers, dampers and damper actuators, fan motor belts, pulleys, bearings, humidifiers and dehumidifiers, air cleaners, thermostats, control devices, sensors, mixing boxes, VAV boxes, terminal reheat units, ductwork, air intakes, and cooling towers. Outdoor air intakes should be checked to verify that they are unobstructed and clear of pollutant sources.[2,4]

It is also important to inspect local exhaust systems and air flow, and air pressure relationships within building areas. Combustion appliances should be checked for odors, leaks, disconnections, deterioration, corrosion and soot (flue components), and downdrafts.[4]

Regular maintenance and calibration of controls are necessary to keep them in good operating order. Control systems are used to switch fans on and off, regulate the temperature of air, or modulate airflow and pressures by controlling fan speed and damper settings.[3]

Scheduling Maintenance

Operation and maintenance documents should specify when HVAC maintenance activities need to be performed. HVAC *checklists* are useful in guiding and documenting HVAC inspections. A sample HVAC Checklist (adapted from the guide *Building Air Quality*) is included in Appendix B of this Manual. Computerized systems are also available to prompt staff to carry out maintenance activities at the proper intervals.[3]

Filters

Filter maintenance should be fully defined in the operation and maintenance manual. The manual should describe all filters required, the basis for change (for example, time, or pressure loss), methods of replacement, service schedule, and record of work completed.[5]

HVAC filters are tested and rated according to Standard 52-76 of ASHRAE. Ratings are available from manufacturers on the basis of this standard for weight arrestance, dust spot efficiency, and dust holding capacity. The dust spot test is a soiling index reflecting fine particle filtering efficiency and is the most useful measure of efficiency available now.[5]

Installing more efficient filters in schools will produce cleaner air, and may help create a more effective teaching and learning environment, reduce absenteeism, and lead to fewer complaints. Although an improved filter may cost more initially, it is important to consider the total costs, since some types of filters may require fewer changes, require less labor, and reduce the need for coil cleaning. Changing from coarse fiber to extended surface filters may be cost effective. Unit ventilator filters may be upgraded from coarse fiber to extended media pleated filters with improved dust spot efficiency, weight arrestance, and longer filter life. In analyzing costs, consider annual costs of filter replacement, labor costs, and coil cleaning costs (for ineffective filters).[5]

All filters impose a back pressure on the HVAC fan. This increased resistance causes a reduction in the airflow unless the fan speed can be increased. Therefore, higher efficiency filters may not be a viable option for an existing unit unless there is sufficient fan speed. This also prevents some new equipment from being supplied with higher efficiency filters, since the manufacturer does not provide an option for a higher horsepower motor. Filter loading from airborne dust will also increase system backpressure and reduce air flow, resulting in reduction of the HVAC system's efficiency.

It is important to recognize that the concentration of contaminants is governed not only by the filter effectiveness, but by the air turnover rate in the room. If the air supply is reduced for long periods of time, the quality of the air will deteriorate, no matter how efficient the filters are.[5]

A more complete discussion of air filters and other air cleaning devices for school HVAC systems is found in the Technical Bulletin by the Maryland State Department of Education, entitled *Air Cleaning Devices for HVAC Supply Systems in Schools*.[5]

Cleaning Coils

Heating and cooling coils expose large areas of metal surface that transfer thermal energy to or from the air supplied to the building. Dirt deposits on these coils reduce their effectiveness. Once coils are dirty, they need to be cleaned--this can be a difficult and costly procedure, usually requiring vacuuming and steam cleaning. Accumulation of dirt can be minimized through the proper maintenance of filters and filter housings in the HVAC system.[5]

The HVAC Space

The maintenance space containing the HVAC should be kept clean and dry, and should not be where cleaning and other maintenance supplies are stored. Unsanitary conditions in the mechanical room are particularly a problem if return air is dumped into and circulated through the room.[3]

Duct Cleaning

Precautions should be taken to prevent dirt, high humidity, or moisture from entering the ductwork. When equipment or duct work downstream of the filters becomes excessively dirty (when you can see accumulation of dust or residue on the duct surfaces), they must be cleaned. The ability to clean the system is mainly determined by the system design and equipment selection. The less access to the equipment, the more difficult the task. Duct cleaning should be performed by properly trained personnel in accordance with standards prepared by the National Air Duct Cleaners Association (NADCA 1992-01, Mechanical Cleaning of Non-Porous Air Conveyance System Components). Note that water-damaged or contaminated porous materials in the ductwork

or other air handling system components should be removed and replaced.[3,5]
If ducts require cleaning, the following precautions should be taken:[3]

- duct cleaning should be scheduled during periods when the building is unoccupied to prevent exposure to chemicals and loosened dirt particles
- negative air pressure that will draw pollutants to a vacuum collection system should be maintained at all times in the duct cleaning area to prevent migration of dust, dirt, and contaminants into occupied areas
- careful attention must be given to protecting ductwork. Duct cleaning performed with high velocity airflow should include gentle, well-controlled brushing to dislodge dust and particles
- use HEPA vacuuming equipment if the vacuum collection unit is inside the occupied space
- if biocides are used, use products registered by EPA according to instructions
- use of sealants to cover interior ductwork surfaces is not recommended
- to reduce microbial pollutants, careful cleaning and sanitizing of all coils and drip pans should be done when ducts are cleaned
- water-damaged or contaminated porous materials in the ductwork or other components should be replaced, and
- after duct cleaning, a preventive maintenance program should be put in place.

Temperature and Humidity Control

Temperature and humidity should be maintained according to ASHRAE Standard 55-1992, *Thermal Environmental Conditions for Human Occupancy*. Acceptable temperature and humidity ranges are discussed on page 6-20 of this Manual.

Maintaining Proper Ventilation

The timing of occupied and unoccupied cycles should be adjusted such that the building is flushed by the ventilation system before occupants arrive. ASHRAE Standard 62-1989 offers guidance on lead and lag times for HVAC equipment. As noted on page 7-7, the lead time during initial occupancy of new or remodeled buildings may be extended to help flush out VOCs from construction materials and furnishings.[6]

The HVAC system should be inspected to verify that it is providing at least the minimum amount of outdoor air (based upon current average daily occupancy) required by the ventilation code in effect at the time of building construction or remodeling. The rate at which outdoor air is supplied to building areas can be estimated from actual measurements or from design criteria and engineering data. Methods for estimating outdoor air quantities are presented in Appendix A of the guide *Building Air Quality*.[2,3]

Outdoor air ventilation rates may vary depending upon whether the building is new or recently renovated, or in operation after the initial break-in period.

Comparison of peak carbon dioxide readings between rooms, between HVAC zones, and at varying heights above the floor, may help to identify and diagnose various building related ventilation deficiencies. When the carbon dioxide level exceeds 1000 ppm, HVAC maintenance personnel should check to make sure that the HVAC system is operating correctly. If it is not, corrective action should be taken.

The HVAC system should operate during normal building occupancy except during emergency HVAC repairs and scheduled HVAC maintenance. The HVAC system or local ventilation should be used during and after normal building occupancy hours if workers are using equipment or products that could result in chemical or particulate releases or exposures. Such work includes waxing floors, cleaning bathrooms, lubricating machinery, or shampooing carpets. Where possible, direct exhaust should be used to eliminate air contaminants at or near their source. Note that Section Seven of this Manual (page 7-7 through 7-13) discusses ventilation and other control measures that may be taken to control contaminants during and after remodeling or renovation. This information may be useful for special building maintenance projects, as outlined above.[2]

Recordkeeping

A written record of HVAC system inspections and maintenance required to be performed under this section should be established.[8]
HVAC inspection and maintenance records or logs should be maintained for at least three years, and should include the specific

actions taken and reasons for actions (e.g., routine maintenance or complaint response), the name and affiliation of the individual performing the activity, and the date of response.[2,7]

Personal Protective Equipment and Safety Standards

Employees performing work on building systems should be trained, and provided with and should use appropriate personal protective equipment as prescribed in WAC 296-24-075 (personal protective and life saving equipment), WAC 296-62-09015 (occupational noise exposure), and WAC 296-62-071 (respiratory protection). In addition, employees should be trained on the control of hazardous energy standard (lock-out, tag-out, WAC 296-24-110) and the confined space entry standard (WAC 296-62-145).

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Section Nine: Controlling Contaminant Sources in and around Schools

Introduction

Section Nine discusses general practices and policies that can be used to maintain good indoor air quality in schools. Tobacco smoking, storage and use of cleaning and maintenance products, dust and microbial growth control, pest control, and asbestos and radon management are addressed.

Note: The practices specified or recommended in this Manual include some that are already required by code or law, and others that are recommendations which may help promote good indoor air quality in schools. It is the responsibility of each school district and other users of the Manual to comply with applicable codes and laws--including those related to building, plumbing, electrical and mechanical systems, fire protection, safety, energy use, and environmental protection. However, all users of the Manual, including school districts, should evaluate the discretionary recommendations presented in this Manual, and adopt or promote those which, in their judgment, are relevant and applicable to their circumstances, and feasible to implement. In the event that any recommendations offered in this Manual are in conflict with any applicable codes or laws, such codes or laws shall take precedence.

Tobacco Smoking

Tobacco smoking on public school campuses (K through 12) in Washington is prohibited by law. Smoking at private schools may be less restrictive, although specific anti-smoking policies at private schools may be enacted. All schools should enforce non-smoking regulations and policies to prevent student and staff exposure to environmental tobacco smoke (secondhand smoke) and degradation of indoor air quality. Nonsmoking policies should include the following[1]

- a statement of the policy or requirement
- a definition of who is covered by the policy or requirement (this should include students, teachers and other staff, and visitors)
- clarification of what constitutes smoking, and
- a statement of the enforcement procedure that will be taken when the policy is violated. Disciplinary actions may include reminders, counseling, written reprimand, and student probation or suspension.

Storage and Use of Cleaning and Maintenance Materials

Indoor air quality complaints can arise from *inadequate housekeeping* that fails to remove dust and other dirt. On the other hand, cleaning materials themselves produce odors and emit a variety of chemicals.[2]

Hazard Communication

It is important to become more familiar with the chemicals in cleaning and maintenance products and their potential toxicity. Select the safest available materials that can achieve your purpose. Review the information provided by product labels and MSDSs. Request information from suppliers about the chemical emissions of products being considered for purchase.[2] The hazard communication standard, WAC 296-62-054, sets forth minimum requirements regarding information, labeling, and training on hazardous chemicals used in the workplace.[3]

Employees, students, and parents should be notified in advance when areas students and staff may occupy will be treated with potentially hazardous chemicals. Notification procedures and timing should be defined by district policy, consistent with any legal requirements for notification.[4]

Use and Storage of Materials

Less toxic materials should be substituted for more toxic materials. In general, water soluble materials should be given preference to organic solvents. Materials that are higher in flash point and/or have a lower vapor pressure are also preferred. Minimize the quantities of potentially hazardous materials purchased, stored, and dispensed.[5]

Use plain soap and water as cleaning agents. Remove dust with a vacuum and/or damp cloth--do not use feather dusters or spray dust collectors.[6]

If products with strong odors or air contaminants must be used, it is best to use them early in weekends or vacation periods to allow fumes to dissipate before the building is reoccupied. Use fans during application.[6] Make sure that vapors from cleaning products are eliminated before air handling systems switch to their unoccupied cycles.[2]

Cleaning and maintenance chemicals, pesticides, and other hazardous chemical in the workplace should be used and stored according to manufacturers' instructions, and according to specific labeling. Avoid storing open containers of unused paints and similar materials. Also, do not store or use hazardous chemicals in mechanical rooms or HVAC plenums.[7]

A local exhaust system should be permanently installed where products containing potential air contaminants are stored.[2]

Dust Control

Frequent conventional vacuuming as a dust control measure does not appear to be effective. On the contrary, conventional vacuums may *increase* airborne dust concentrations. Vacuuming is least effective for the very small particle sizes that have the greatest potential to create allergy problems or asthma. Vacuuming with a HEPA (high efficiency particulate air) type cleaner or those that entrain dust in a liquid medium (wet-vacs) are more effective. Caution should be used with liquid medium systems, since they can distribute dust mite antigens in an aerosol form. To minimize problems with liquid medium systems, vacuuming should be performed after normal school hours to allow antigens to dissipate before peak building occupancy.[8]

Door mats placed at building entrances may also be used to help prevent soiling of carpets with dust, debris, as well as moisture.

Preventing Microbial Growth following Spills or Building Leaks

The building should be inspected periodically for discolored or wet ceiling tiles, or leaks indicating water problems. In case of leakage, it is useful to have wet vacuums, submersible pumps, mops, and other spill cleanup equipment available.[9]

Microbial growth should be minimized by containing, diverting, and/or repairing known water and fluid leaks and spills as soon as possible, and by cleaning, drying, or removing wet materials such as carpet, upholstery, and ceiling tiles. Drying should be undertaken within twenty-four hours after discovery. Should moss, mold, or algae be found growing on building surfaces within conditioned spaces or in HVAC system components, it should be carefully removed to minimize the release of microbial contaminants into the indoor atmosphere, and actions should be taken to prevent further growth.[3]

Pest Control

As the public becomes more aware of the health and environmental risks of pesticides, its interests in seeking the use of effective alternative pest control methods increase. School officials should adopt integrated pest management (IPM) as an alternative to regular spraying of pesticides (insecticides, herbicides, fungicides) at schools. Effective and safe measures to control pests in schools are consistent with and complement measures to ensure good indoor air quality.

Integrated Pest Management

IPM can reduce the use of pesticides and provide an economical method of pest suppression. IPM programs use current information on the life cycles of pests and their interaction with the environment. Pest populations are reduced and controlled by creating inhospitable environments, by removing some of the basic elements pests need to survive, or by blocking their access into buildings. Pests may also be managed by other methods, such as traps, vacuums, or the judicious use of pesticides. IPM programs consist of a cycle of inspecting, identifying, monitoring, evaluating, and choosing the appropriate method of control.[10]

Pest prevention measures include the following:[10]

- maintain sanitation and structural repair of buildings
- employ screens, traps, and other devices to keep pests from entering buildings
- use weed removal devices

- keep food sources only in designated areas, with food containers sealed

- keep desks and lockers clean

- keep carpeted areas clean, dry, and free of food residues

- remove wastes at the end of each day

- clean floor drains, strainers, and grates, and

- repair leaks and other plumbing problems to deny water to pests.

Any pesticides that are used should be applied by licensed applicators (which may be commercial applicators or school employees) when students and staff are not present. Where pesticide use is deemed to be necessary, select pesticides that are species-specific (to the extent possible) and attempt to minimize toxicity for humans and non-target species. Ask contractors or vendors to provide EPA labels and MSDSs. Make sure that pesticides are stored and handled properly, consistent with their EPA labels.[2,10]

Control measures to restrict pesticide *use*, and to restrict *access* to pesticides is essential. Notification should be provided to students, staff, and parents at least 24 hours in advance of upcoming pesticide application, or as otherwise called for in the school policy. Warning signs should be posted around areas before and after pesticides have been applied. Where possible, the time of application should be restricted to periods when the school is not occupied or when outdoor areas are not scheduled for use. School emergency management plans should also address accidents involving pesticides.[10,11]

Following the application of pesticides, all building areas which may be affected should be well ventilated. Consider using temporary exhaust systems to remove contaminants during the work. It may be necessary to modify the HVAC system operation during and after pest control activities, such as running air handling units on maximum outdoor air to allow several complete air exchanges before occupants reenter the treated space.[2]

When pesticides are applied outdoors, special precautions should be taken. Pesticides should not be applied near building air intakes. Windows near or downwind of pesticide application areas should be kept closed.

Records on pesticide application should be kept as required by the Washington Pesticide Application Act, Chapter 17.21 RCW. Records must include the time and location of application, the specific product used, and the concentration and quantity applied. Specific recordkeeping requirements are identified in the statute.

For further information on Integrated Pest Management in schools, refer to EPA document 735-F-93-012, entitled *Pest Control in the School Environment: Adopting Integrated Pest Management*.[10]
Additional information on IPM may be obtained from the Washington State University Cooperative Extension Service, Urban IPM Clearinghouse, phone (206) 205-8616. Information on the health effects of pesticides may be obtained from the Washington State Department of Health Pesticide Section, phone (360) 753-3518.

Information on alternatives to use of pesticides for control of head lice may be obtained from health care professionals, or from documents such as *Control of Communicable Diseases in Man*, published by the American Public Health Association, Washington, D.C.

Managing Asbestos

Asbestos management in schools has been governed in large part through the Federal Asbestos Hazard Emergency Response Act (AHERA) of 1986. This act required schools to identify all locations of asbestos containing building materials, and to prepare an asbestos management plan for each building.

Management or abatement methods include one or more of the following: operation and maintenance; repair; encapsulation; enclosure; and removal. There are several ongoing asbestos management tasks which should be undertaken to comply with the law. Key tasks include the following:[12]

all maintenance and custodial employees must attend at least a two-hour training course in asbestos awareness, and new

- maintenance employees must receive instruction within 60 days following the commencement of their employment. Any maintenance and custodial employees who perform any activities which may disturb asbestos must attend at least 30 hours of training

- any employee working on any aspect of an asbestos project must be certified and accredited by the state and/or EPA

- schools must properly transport and dispose of asbestos waste

- schools must use a properly trained AHERA designated person to ensure that asbestos-related activities are properly conducted and entered into the asbestos management plan

- short-term workers (telephone repair, electricians, plumbers, for instance) must be informed of the locations of asbestos containing building materials in the building

- warning labels must be posted in routine maintenance areas (boiler rooms, pipe tunnels, air handling rooms, for instance) to prominently identify any asbestos containing materials or suspected materials

- school building occupants (faculty, staff, parents, legal guardians) must be notified in writing at least once during each school year regarding the status of the building's on-going asbestos activities, including information on the availability for the public to review the asbestos management plan during normal business hours

- at least once every six months, the school must conduct a visual surveillance of all asbestos containing materials and assumed materials in each building to see if there have been any changes in the conditions of the asbestos

- records must be kept of the surveillance and findings, and

- every three years, schools must conduct an inspection to identify all locations of friable and non-friable asbestos.

Even schools with no asbestos detected need to comply with certain requirements of AHERA. For detailed information on requirements for asbestos management, contact EPA or the Washington Department of Labor & Industries.

EPA publications on asbestos management include*Asbestos-Containing Materials in Schools--Final Rule (October 30, 1987); 100 Commonly Asked Questions About the New AHERA Asbestos-in-Schools Rule; A Guide to Performing Reinspections Under the Asbestos Hazard Emergency Response Act; Answers to the Most Frequently Asked Questions About Reinspections Under the AHERA; Managing Asbestos in Place: A Building Owner's Guide to Operations and Maintenance Programs for Asbestos-Containing Materials; Guidance for Controlling Asbestos-Containing Materials in Buildings;* and *Asbestos Model Accreditation Plan--Interim Final Rule (February 3, 1994).*

Radon Management

Many factors contribute to the entry of radon gas into a school building. Radon levels may vary from room to room within the same school building. Factors which determine why some schools have elevated radon levels and others do not are affected by the concentration of radon in the soil gas (source strength) and permeability of the soil gas (gas mobility) under the school, the structure and construction of the school building, and the type, operation, and maintenance of the HVAC system.[13]

Depending upon their design and operation, HVAC systems can influence radon levels in schools by increasing ventilation (diluting indoor radon concentrations with outdoor air), decreasing ventilation (allowing radon gas to build up), pressurizing a building (keeping radon out), and depressurizing a building (drawing radon inside).[13]

Design, construction, and operation and maintenance will influence radon levels in schools. The frequency and thoroughness of HVAC maintenance plays an important role in the control of radon levels.

For additional information on radon in schools, refer to page 5-4 and 5-5 of this Manual. Several useful reference documents prepared by EPA and the Washington State Department of Health on radon are identified.

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Section Ten: Controlling Contaminant Sources in Classrooms, Offices, and Special Use Areas

Introduction

There are a multitude of activities occurring within schools. Many of these activities have the potential to affect the quality of the indoor air for students and staff. *Special attention to indoor air quality issues is needed during building design and ultimately building operation for each of these activities and building uses.* Methods to maintain good indoor air quality are discussed for the following areas within school buildings:

- general offices and classrooms
- staff work rooms and printing rooms
- food handling areas
- locker rooms
- science laboratories
- art and theater rooms
- vocational arts areas (these areas include wood, metal, auto, vocational-agricultural shops, and jewelry repair) and
- swimming pools.

Note: The practices specified or recommended in this Manual include some that are already required by code or law, and others that are recommendations which may help promote good indoor air quality in schools. It is the responsibility of each school district and other users of the Manual to comply with applicable codes and laws--including those related to building, plumbing, electrical and mechanical systems, fire protection, safety, energy *use, and environmental protection. However, all users of the Manual, including school districts, should evaluate the discretionary recommendations presented in this Manual, and adopt or promote those which, in their judgment, are relevant and applicable to their circumstances, and feasible to implement. In the event that any recommendations offered in this Manual are in conflict with any applicable codes or laws, such codes or laws shall take precedence. Note that some of the recommended activities are in addition to those customarily performed by outside consultants or in-house staff providing design or related professional services for school districts.*

General Offices and Classrooms

Personal Hygiene

Schools are unique buildings from a public health perspective because they accommodate many people within a small area compared to most buildings. This close proximity increases the potential for contaminants to pass among students and staff.

Raising students' awareness about the effects of their habits on the well-being of other students can help reduce indoor air quality problems. Students, parents, and staff should be informed about the importance of good personal hygiene in preventing the spread of contagious diseases. This includes proper hand washing, and covering coughs and sneezes.

Written materials on personal hygiene may be available from local health departments. Individual instruction and counseling should be provided when necessary. It may be valuable for the school district to collaborate with parent groups to consider offering family indoor air quality education programs in schools. In addition, a teacher workshop on health issues that addresses indoor air quality may be useful.[1]

Maintaining Clean Classrooms and Offices

Regular and thorough classroom and office cleaning is important to ensure good indoor air quality. Unsanitary conditions attract insects and vermin, leading to possible indoor air quality problems from pesticide use or animal allergens. Cleaning should include dusting, mopping, sweeping the floors, regular vacuuming, removal of trash, and removal of food. To reduce the potential for contamination from food spillage, food should be eaten in the cafeteria or gymnasium, not in classrooms. This is particularly important in classrooms that are carpeted.[1]

Spills should be cleaned up promptly. For spills on carpets involving more than a quart of water, contact custodial staff immediately (carpets need to be cleaned and dried within 24 hours). Request that the unit ventilator filter be replaced if spilled liquid goes into the unit. Also report previous spills on carpets or in unit ventilators, since they can affect current air quality.[1]

A vacuuming schedule should be developed for all carpet areas based on traffic rate and the potential for soiling. Daily vacuuming will be required in the majority of carpeted areas when a school is in full use. Vacuums with revolving brushes and strong suction are the best for cleaning carpets which have been glued down. At least 5 micron filtration is recommended to reduce dispersion of fine particles by vacuums into the air. If there are indoor air quality problems, a HEPA filtration vacuum should be used. Desks, tables, and chairs should be moved at least weekly to allow the entire carpet to be cleaned.[2]

Stains are most easily removed when they get prompt attention. A spot removal kit should be available in every carpeted building. Some spot cleaners are solvent-based, but other citrus-based products are available.[2]

Hot water extraction and shampooing are very effective together to clean carpets. Hot water extraction alone may be done as follows: heavy traffic areas should be cleaned three times per year; medium traffic areas should be cleaned twice per year; and light traffic areas should be cleaned once per year. If carpets are shampooed several times each year, then one hot water extraction during the year is usually sufficient. Excessive wetting of carpets should be avoided. Staff and students should also be informed of the need to avoid spilling milk and other liquids on the carpet. Mats or foot grilles at building entrances should be used to prevent soiling and soaking of carpets.[2]

Certain people are sensitive to animal fur, dander, body fluids, and animal waste products and may experience allergic reactions to these irritants. Some individuals may become sensitized by repeated exposure to animal allergens. Alternatives to keeping animals in classrooms should be considered. If animals are present in classrooms, they should be kept in cages as much as possible, and should not roam freely. Cages should be cleaned regularly. Animals should be located away from ventilation system vents to avoid circulating allergens through the room.[1]

Special care can be taken with sensitive students. Consult the school nurse about student allergies, ask parents about potential animal allergies in a note taken home by students, or during conferences with parents. Check for allergies when new students enter the class, and locate sensitive students away from animals and animal cages.[1]

Some staff and students may be sensitive to personal body care products. School employees should be encouraged to minimize the use of perfume, cologne, scented aftershave, perfumed soaps, or hairspray. Students in the higher grade levels should receive similar guidance.[3]

Rugs and furniture may also be sources of dust, VOCs, and allergens. Items which may present indoor air quality problems should not be brought into classrooms or offices by teachers.

Other Classroom and Office Maintenance Practices

Drain traps can become a problem when the water in the drain trap evaporates due to infrequent use, allowing sewer gases to enter the room. Drain traps should be filled regularly if they are infrequently used. These include floor drains, sinks, and toilets.[1]

Excess moisture contributes to the growth of mold and mildew which causes odors and other indoor air quality problems. Excess moisture is the result of condensation on cold surfaces, leaking or spilled liquid, or excess humidity. Check for condensate on cold surfaces. Check for leaks from the plumbing or roof. Also look at ceiling tiles and walls for patches of discoloration, and around sinks and lavatories for signs of leaks.[1]

Comfort factors should also be checked periodically to make sure that the students and staff perception of the indoor environment is acceptable. Check the temperature and humidity, locate any drafts, and determine if there is a problem with direct sunlight shining on occupants.[1]

Some changes in classrooms or offices may affect the effectiveness of ventilation in these rooms. When office or instructional areas are changed with the addition or removal of equipment, furniture, personnel, or partitions, there should be consideration given to modification of the air distribution system. Also, make sure that the airflow from the HVAC is not diverted or obstructed by books, papers, or other obstacles.[1]

Staff Work Rooms and Printing Rooms

Indoor air quality may be affected by duplicating equipment (or the products found in the equipment) in staff work rooms and printing rooms. This equipment includes*photocopiers, spirit duplicating machines, mimeograph machines, and diazo dyeline (blue print) machines and electronic stencil makers.*

Copiers and Printers

Photocopiers produce ozone as the major contaminant. Most manufacturers recommend that the area in the vicinity of photocopiers be mechanically ventilated at the rate of at least four air changes per hour (0.5 cubic feet per minute per square foot of floor space, assuming an 8 ft. ceiling). Ventilation by a central air conditioning system with total air circulation through the space at this rate should be satisfactory. In most cases, no direct exhaust to the outdoors is needed, although more stringent manufacturer's instructions regarding ventilation should be followed.[5]

Laser printers also produce ozone and other air contaminants in low levels. These printers should be operated in well ventilated areas, and care should be taken to replace ozone filters according to manufacturer recommendations.

Spirit Duplicating Machines

Spirit duplicating machines use methyl alcohol as a duplicating fluid. Methyl alcohol is a flammable liquid and must be stored according to local fire codes (for instance, over ten gallons must be stored in an approved metal cabinet). Overexposure to methyl alcohol vapors may cause dizziness, nausea, vomiting, irritation and burning of the eyes, and blurred vision or temporary vision loss. Use of low methyl alcohol content duplicating fluid can greatly reduce the inhalation and fire hazard.[5]

Spirit duplicators are best located in a separate room dedicated to copying, with the room well ventilated and the duplicating equipment exhausted to the outdoors at a rate of eight air changes per hour. If possible, the exhaust should be on a wall *opposite* the operator at the equipment height and should maintain a slight negative pressure to limit odor permeation to other areas.[5]

Due to the problems associated with spirit duplicators, careful consideration should be given to any decision to purchase and use one. However, if spirit duplicators are used, it is important that proper ventilation be provided and fire codes for material storage be followed. Anyone operating the equipment should have training which addresses safety precautions. The following precautions should be taken:[6]

- exposed skin should be washed after each duplicating run
- allow duplicating paper to dry before collating and stapling
- make sure that only properly trained staff use equipment
- do not use duplicating fluid as a cleanup solvent, and
- avoid spilling, and develop spill procedures that follow the manufacturer's recommendations.

Mimeograph Machines

Mimeograph machines use black mimeograph ink, which primarily is untreated napthenic oil. It is not normally an inhalation hazard and requires no special ventilation.[5]

Dyeline Copiers

Diazo dyeline copiers use ammonia in an aqueous solution. This solution can be a strong irritant affecting the eyes and mucous membranes. The equipment is designed to allow direct ducting to the outdoors. Because of its potential for air contamination, it is normally located in a separate room. In addition to the direct outdoor machine exhaust, the room should be exhausted independently of the machine, and not recirculated. The room exhaust should create a slight negative pressure to limit permeation of odors to other spaces.[5]

Stencil Makers

Stencil makers usually require no special ventilation. The contaminants generated during stencil making are in trace amounts, and typically are located only in the immediate vicinity of the equipment. An exhaust or return air register near the point of contaminant release should be sufficient to control any odor.[5]

For each copy or printing machine described above, periodic inspection and maintenance should be performed in accordance with manufacturers' recommendations.

Food Handling Areas

Activities in the school kitchen generate odors, moisture, food waste, and other trash, all of which must be managed carefully to avoid indoor air quality problems.

Maintaining Cleanliness

It is essential to maintain cleanliness in the food service area. Food waste and food-contaminated paper products produce odors and encourage insects and vermin. After cooking, food scraps and crumbs should be removed and disposed of properly, counters should be wiped clean, and floors should be swept and wet mopped to remove food. Containers should be well sealed with no traces of food left on the outside surfaces of containers.[1]

Periodically inspect for signs of microbial activity such as slime and algae. Check upper walls and ceilings for evidence of mold growth. Inspect the kitchen for plumbing leaks. Also check sink faucets and areas under sinks for stains, discoloration, and/or damp areas.[1]

Exhaust Fans

It is important to confirm that local exhaust fans function properly. They should be switched on whenever cooking, dishwashing, and cleaning are taking place.[1]

Depending upon the configuration of the school, operating kitchen fans may draw air from adjacent loading docks. If delivery trucks or other vehicles are idling at the dock, exhaust fumes can be drawn in and degrade indoor air quality and cause adverse health effects. Signs should be placed to remind drivers to avoid idling their engines in receiving areas. Doors between the receiving area and the kitchen should be closed whenever possible. If these control methods are not effective, it may be desirable to consider modifying fan and air intake locations to prevent contamination problems.[1]

To help prevent the spread of odors throughout the school building, kitchens should have separate ventilation systems. Kitchen air should not be circulated to other parts of the building.

Gas Appliances

If gas appliances are used, confirm that they function properly and are venting outdoors. Check for backdrafting and gas leaks, combustion gas odors, or natural gas odors.[1]

Waste Storage

Proper placement of dumpsters will also prevent odors from entering the building and minimizes opportunities for insects and vermin to enter the building. Wastes should be placed in appropriate containers with lids that close securely. Dumpster lids should be kept closed, except when dumpsters are being used. Dumpsters should be kept well away from air intake vents, operable windows, and food service doors.[1]

Locker Rooms

There are a number of locker room conditions that can affect indoor air quality. These conditions include standing water, high humidity, warm temperatures, and damp or dirty clothing.[1]

Lockers should be built with an air space behind them through which return air is circulated. This will draw odors out of garments and equipment stored in lockers.

Locker rooms should be kept clean. On a regular basis wet towels and soiled practice uniforms should be removed and laundered, and students should be asked to take soiled personal clothes home regularly for laundering.[1]

Some of the products used to control germs and odors in the locker room (such as disinfectants) may also contribute to indoor air quality problems if these materials are improperly used. Chemical cleaners and disinfectants should be used only when students are not in the locker rooms, and exhaust fans should be operated to remove cleaning product vapors and odors. Although improper use of cleaners may produce indoor air quality problems, it is important that showers and other locker room areas are cleaned regularly and properly.[1]

Science Laboratories

Most school science laboratories contain a wide variety of chemicals that are used in instruction. These include radioactive materials, explosives, corrosives, flammable liquids, oxidizers, and toxic materials.

These materials can present indoor air quality problems when they are released into the school environment. They can become airborne through evaporation, by generation of dust particles, and release of gases, aerosols, and fumes by combustion or other chemical reactions. Health effects can range from noxious and irritating odors to serious acute respiratory effects and chronic disease or injury.[7]

Minimize Use of the Most Hazardous Chemicals

School systems should use the least hazardous chemical whenever possible and eliminate carcinogenic, highly toxic, and highly reactive chemicals from the science laboratories unless there is some overriding educational benefit, or they are used in a well-controlled demonstration. MSDSs should be kept on file for all chemicals used in science laboratories. Reference should be made to MSDSs which list carcinogens, and provide numerical ratings for hazards such as flammability and reactivity according to the NFPA Standard 704. Ratings of 3 or 4 in any category may be considered highly hazardous. Diluted substances rather than concentrates should be used where possible. Another alternative is to use films or video tapes for demonstration purposes.[7]

Ether should be replaced with non-toxic substitutes where possible. Non-formaldehyde solutions for preserving biological specimens should be used. Alternatives to mercury barometers and thermometers should be used, since breakage or spillage of mercury creates a hazard. In addition, hot plates and a water bath should be used in place of alcohol lamps.[7]

Chemical Storage

Proper storage of chemicals is essential. This begins with an inventory of each chemical by container, with the date of receipt, date of opening, and scheduled disposal (if appropriate). Proper inventorying should lead to placement of orders for chemicals to minimize the quantities stockpiled. Storage areas should be organized such that only compatible chemicals are stored together, to prevent fires, explosion, or excessive heat. Chemical suppliers can provide instructions for proper storage of laboratory chemicals used in schools. Storage areas should also be separated from main classrooms and ventilated separately. Chemical storage rooms may be required to contain smoke and heat detectors, explosion proof lighting, static-free switches and electrical outlets, and be air conditioned with humidity control. Building and fire codes should be used to guide the design, construction, and operation of chemical storage areas.[7]

Use of Plants, Animals, Microbes

Some courses involve experiments with plants and microbes which may either be toxic or produce allergic spores which can become airborne. Pathogenic and non-pathogenic microbes may be intentionally or unintentionally cultured and spread to other parts of the school if proper procedures are not used.[7]

Animals used in labs may also present problems. Animal dander, hair, and saliva and insect parts may cause allergic reactions in some teachers and students. Care should be taken to ensure that animal cages and bedding do not become reservoirs for disease carrying parasites and infectious agents. Only non-pathogenic organisms should be cultured in the laboratory, and they should be treated as if they were pathogenic.[7]

Exhaust Emissions

Toxic or otherwise objectionable emissions should be exhausted directly outdoors from the point of generation, using a lab hood. To avoid the spread of odors through other school spaces, the lab should be kept under negative pressure when in use, and the air should not be recirculated through a central air system.[7]

Lab hoods should be used to capture all gases or aerosols released within it. Hood location is very important--when possible they should be on an outer wall and far from any doorway to avoid turbulence from opening and closing doors. The outside exhaust must be located to avoid re-entry into the building by way of open windows, fresh air intakes, or other means. Hoods should be checked regularly for proper air flow.[6]

Chemical Hygiene

It is appropriate to have a good lab chemical hygiene plan, such as that required under WAC 296-62-40009. The plan should include the following elements:

- standard operating procedures to ensure health and safety for students and staff
- methods to reduce personal exposures to chemicals through engineering controls, personal protective equipment, and good hygiene practices
- measures to ensure equipment is operating properly
- information and training on the hazards and protection methods, including emergency plans
- procedures for approving lab activities
- procedures for medical consultation and examination
- identification of personnel responsible for implementing the chemical hygiene plan, and
- a policy for incorporating higher levels of protection for work involving very toxic or hazardous chemicals.

Lab Drains

Lab drains must also be kept in working order. Sediment in drain traps can promote the growth and accumulation of microorganisms. Antisiphon traps in sinks must contain water to back into the indoor air. Cupsinks in lab fume hoods and on benches frequently dry out, and have often been found to be a source of odors. The problem can be resolved by periodically running water in these drains, or plugging unused drains with a stopper.[4]

Art and Theater Rooms

Hazardous Materials

Student art materials that may affect indoor air quality during their use and storage include clays, paints, markers, pigments, varnishes and lacquers, acids, inks, solvents and adhesives. Theater crafts involve preparing and using props, scenery, lighting and costumes. Materials used in theater productions may include many of the above-mentioned products, and involve the use of other materials, such as sawdust, and welding or soldering materials.[6]

Clays and glazes are composed of minerals and metal compounds. When these materials are handled in their dry form their dusts can become airborne and easily inhaled. Some of the dusts in standard ceramic work are hazardous, particularly crystalline free silica. When greenware is fired in a kiln, the high temperature causes emissions of materials such as sulfur dioxide, metals, nitrogen dioxide, carbon monoxide, organic compounds, and ozone. The kiln itself may heat up a space excessively, causing discomfort to occupants.[5]

Less Toxic Alternatives

It is important to request a MSDS for all prospective art materials, and choose the ones that are safest. The Art and Craft Materials Institute is a non-profit association of manufacturers of children's quality art materials. The AP (Approved Product) Seal appears on certain packages and containers of children's art materials, indicating that they are approved as non-toxic. The Center for Safety in Arts and California Department of Education also developed a list of products that are safe for children from grades K-6. Lists of safer products are available from these organizations. Their addresses are listed in Section Twelve of this Manual.[1]

Safe Practices

Good safety, handling, and storage practices should be used in art rooms. These practices include the following:[1]

- have appropriate procedures and supplies available for spill control
- label all hazardous supplies with date of receipt/preparation and pertinent precautions

- keep lids on containers when not in use
- follow recommended procedures for disposal of used substances
- supply storage should be separate from main classroom area where possible, and should be ventilated
- substitute less hazardous or non-hazardous materials when possible
- use fume hoods and local exhaust as necessary
- isolate contaminant producing activities or operations
- use moist premixed rather than powdered products, and
- use instructional techniques that require the least amount of materials.

As noted above, kilns are a potential source of indoor air pollutants. The kiln should be fired at times of lower occupancy. Preference should be given to the use of electric kilns in purchasing decisions, since there are fewer emissions than gas-fired kilns. Also, outside groups that use the art facility after school should not use glazes that are prohibited for use by students of the school.[5]

Kilns should be isolated in a separate kiln room if possible, and should have local exhaust ventilation. Usually a canopy hood exhaust should be used, although some school remodeling projects may add on kiln vents with exhaust directed through an exterior wall. Kilns may also be placed outside the art room in a partially enclosed, covered porch away from building air intakes. General guidelines for design of canopy hoods are listed in the State of Maryland Technical Bulletin entitled *Guidelines for Controlling Indoor Air Quality Associated with Kilns, Copiers, and Welding in Schools*.[5]

Vocational Art Areas

Industrial and vocational art areas may involve operations that have potential health hazards, including the potential to affect indoor air quality. Such operations may include ceramic coating, grinding, forming and forging, use of molten metals, paint spraying, plating, operation of gas furnaces or ovens for heating or drying products, welding, wood working, jewelry repair, vocational-agricultural activities, and operation of motor vehicles and equipment. Solvents, paints, varnishes, lacquers, acids, adhesives, glues, waxes, and other products containing hazardous constituents may be used.[6]

This part of Section Ten discusses indoor air quality with respect to several of the vocational arts activities listed above.

Welding and Related Activities

Welding, brazing, and thermal cutting processes generate many types of metal fumes and gases which may present health hazards. Metal fumes are often largely from filler metal. Fumes may also originate from the base metal, coatings to the base metal, and from the flux or electrode coatings. Gases may come from the arc, or changes in the surrounding air. Some metal fumes may only be irritants, but others can cause long-term damage to the exposed welder.[5,6]

Control can be achieved through good work practices and properly designed engineering controls. Work practices include wearing personal protective clothing, masks, practicing good housekeeping, sanitation, and personal hygiene, handling compressed gases safely, knowing how to handle emergency situations, and using HEPA vacuums.[5]

Ventilation must prevent contaminants generated during the welding process from passing through the welder's breathing zone. Mechanical ventilation is normally required, and consists of local exhaust, local supply, and dilution ventilation. Local exhaust may be provided by either fixed enclosures or freely movable hoods placed as close to the welding operation as practicable. After a system is installed and set in operation, its performance should be checked to see that it meets engineering specifications, including rates of air flow, duct velocities, and negative pressures. General guidelines for design and operation of exhaust hoods may be found in the State of Maryland Technical Bulletin entitled *Guidelines for Controlling Indoor Air Quality Associated with Kilns, Copiers, and Welding in Schools*.[5,6]

Flammable gas and oxygen cylinders should be separately stored according to fire codes. Welding and cutting should also be done at a safe distance from flammable materials.[6]

Spray Booths

Spray booths are used for painting, cementing, glazing, metalizing, cleaning, or welding. Various hazardous materials may be released as dust, vapor, or mists. Care must be taken to follow all applicable codes (including fire and electrical codes) in the design and operation of spray booths. Following are design, construction, and operational recommendations:[6]

- use noncombustible material, such as steel, concrete, or masonry in construction
- all spraying areas should be provided with mechanical ventilation which must be in operation at all times spraying operations are conducted, and following spraying to allow vapors to be exhausted
- assure a ventilation rate across the face of the paint spray booth of at least 100 feet per minute
- equip spray booths with the proper filter to remove dust and mists generated in the spraying process--dust filters do not remove mists, so special arrestor pads should be used
- design booths to direct air flow toward the exhaust outlet
- explosion proof lights and switches and exhaust fan motors (if inside the booth) must be provided as required by code
- construct the interior of booths to be smooth and continuous without edges or areas for pocketing of residues and to facilitate cleaning and washing
- interior surfaces should be kept free of combustible deposits
- portable lamps should be kept away from spray operations, and
- fire suppression sprinkler heads should be kept clean.

General Safety Precautions in Vocational Arts Rooms

Since hazardous materials are often used in vocational arts areas, safety precautions must be taken, including the following:[1,4,6]

read labels, use MSDSs, and identify all precautions for health

- substitute a less harmful material for one that is a greater threat to health and indoor air quality

- follow manufacturers' recommendations for safety, handling, and storage of materials

- develop appropriate procedures and have supplies available for spill control

- follow recommended procedures for disposal of used substances

- secure gas cylinders

- locate storage areas away from the main classroom area and make sure it is ventilated separately

- change or isolate a process to minimize student contact

- use wet methods to reduce dust

- HEPA vacuums should be used in automotive and industrial shops and craft activities that generate dusts, fumes, or particulates--dry sweeping should be curtailed in these areas, although damp mopping may be used to clean floors

- use appropriate personal protective equipment (for instance, gloves, masks, eye protection), and

- exercise good housekeeping, including cleanliness, proper waste disposal, and washing.

Special Ventilation Considerations in Vocational Arts Rooms

Vocational arts facilities should also be thermally treated for year-round use with special attention being given to mechanically-forced air systems that provide for the ventilation and circulation of fresh air. The amount of ventilation air required is dependent upon the types of activities to be conducted. This should be determined early in the design process, because it is important for occupant comfort and protection of equipment from corrosion due to excess humidity. Special consideration should be given to local exhaust from operations, such as fumes generated by welding, furnaces, masonry dust, and spray painting. An exhaust system must be provided for each welding booth area. Engine fumes must be exhausted to the outside where internal combustion engines are used. Separate HVAC controls for industrial arts facilities should be provided if evening programs or use of the industrial arts facility is planned at times other than during the day. An exhaust system with HEPA filters should be used when changing brake linings. Other precautions for brake repair should be followed, including those listed in WAC 296-62-07745, Work Practices and Engineering Controls for Automotive Brake Repair Operations.[6]

Swimming Pools

In the design of school pool facilities, it is important to ensure that a separate ventilation system is used. This is needed to prevent air exhausted from the pool facility from being recirculated into other occupied areas. In addition, ASHRAE Standard 62-1989 calls for a minimum of 0.5 cfm/sq. ft. of outdoor air supplied to pool and deck areas, with higher levels provided as necessary to control humidity.

It is also critical that the design ensures good mixing of outdoor air in the pool area, including the breathing zone of swimmers--just a few inches above the pool water level. Many indoor air quality complaints come from swimmers who breathe vapors containing irritating levels of chlorine compounds.

State regulations adopted by the Board of Health (Chapter 246-260 WAC) govern water recreation facilities. In operation of pools, care should be taken to use the proper level of disinfectants, as called for in WAC 246-260-070. If chlorine gas is used, special precautions must be taken during design, construction, and operation of chlorine rooms to minimize the potential for a chlorine leak, and to reduce the potential exposure of people to chlorine gas.

These precautions include locating the chlorine room with consideration of prevailing winds to dissipate leaked chlorine away from the pool facility, and meeting specific requirements for the mechanical ventilation system. Requirements for the chlorine room ventilation system include locating the air inlet as far as possible from fan intake to promote good circulation; providing a minimum of one air change per minute in the chlorine room when the fan is operating (when the room is occupied); ensuring that there is adequate suction from the fan near the floor; and locating the exhaust for the fan and chlorinator vent away from the air intake to prevent undue hazard for pool users.

References

1. U.S. Environmental Protection Agency. 1995. Indoor Air Quality Tools for Schools. EPA 402-K-95-001. Washington, D.C. Teacher's Checklist, Administrative Staff Checklist, Health Officer's Checklist, Building Maintenance Checklist, Food Service Checklist.

2. Maryland State Department of Education. 1993. Technical Bulletin--Carpet and Indoor Air Quality in Schools. Division of Business Services. Baltimore, Maryland. p. 2-8.

3. Med-Tox Northwest. 1994. Indoor Air Quality Investigation: Everett School District No. 2, North Middle School. Report Dated June 10, 1994. Kent, Washington. p. 8.

4. Anne Arundel County Public Schools. 1989. Indoor Air Quality Management Program. Annapolis, Maryland. p. 60, 62-64.

5. Maryland State Department of Education. 1991. Technical Bulletin--Guidelines for Controlling Indoor Air Quality Problems Associated with Kilns, Copiers, and Welding in Schools. Division of Business Services. Baltimore, Maryland. p. 2-8.

6. Maryland State Department of Education. 1987. Indoor Air Quality--Maryland Public Schools. Office of Administration and Finance. Baltimore, Maryland. p. 34, 35.

7. Maryland State Department of Education. 1994. Technical Bulletin--Science Laboratories and Indoor Air Quality in Schools. Division of Business Services. Baltimore, Maryland. p. 2-8.

Section Eleven: Indoor Air Quality Planning and Management

Introduction

This section of the Manual addresses ways to maintain good indoor air quality once a school is operational, and provides an overview of the key steps that should be taken when indoor air quality problems arise. This section focuses primarily on administrative and management issues, and compliments the recommendations for HVAC maintenance and other operational and maintenance practices discussed in Section Four.

A guide prepared by the U.S. Environmental Protection Agency entitled *Indoor Air Quality Tools for Schools* offers many helpful ideas and recommendations for ensuring good indoor air quality in schools. The guide discusses the role and function of the IAQ coordinator, describes the steps involved in writing an indoor air quality management plan, and provides several indoor air quality checklists and forms. However, the guide does not address school siting, design, and construction issues addressed in Sections Four through Ten of this Best Management Practices Manual.

Designating or Maintaining an Indoor Air Quality Coordinator

Section Four (page 4-4) recommended that an indoor air quality (IAQ) coordinator be assigned to verify that practices to ensure good indoor air quality are carried out in school siting, design, and construction. Once the school is operational, it is important to maintain the position of IAQ coordinator to help ensure that good building management practices are followed, and that staff are available to make sure that problems and complaints related to indoor air are properly handled.

The IAQ coordinator may serve several functions in the school: coordinating a team of school staff and outside interests with the goal of maintaining good indoor air quality; acting as a point of contact for information, and receipt of indoor air quality complaints; and helping to facilitate responses to indoor air quality complaints and problems. The IAQ coordinator may be the key point of contact for the following groups:[1]

- custodians, facility operators
- teachers and administrative staff
- students and parents
- contract service providers, as well as architects, engineers, and contractors associated with building renovations and repairs
- the local health department
- school boards and site councils, and
- the news media.

The functions of the IAQ coordinator in the school may be performed at the upper level of administration in a school, school district, or Educational Service District by personnel such as a safety officer, risk manager, principal, vice principal, business official, facilities director, or maintenance supervisor. The functions may also be performed by staff at a lower level within the school district organization. One potential advantage of using upper level administrative personnel to serve as IAQ coordinator is that such personnel are more likely to have greater control over decisions affecting indoor air quality than staff at lower levels.

Any individual assigned to serve as IAQ coordinator should have the skills to organize, manage, and communicate well with others and should have sufficient time to devote to such a function. The individual assigned does not need to have specific technical skills related to indoor air quality, although knowledge of indoor air quality issues should be developed through training courses. The individual selected as IAQ coordinator at this stage may be a different person than the one designated during the school siting, design, and construction phases.

Preparing an Indoor Air Quality Management Plan

On pages 6-3 and 6-4, this Manual recommended that an *indoor pollutant source control plan* be prepared. The indoor pollutant source control plan addressed site and facility planning issues, HVAC system design, and selection of materials, interior finishes, and furnishings to reduce building emissions. Note that the indoor pollutant source control plan *does not* address building operational issues which are also essential in maintaining good indoor air quality.

An indoor air quality management plan should be prepared and implemented to ensure healthy indoor air quality in operating schools. A key element in activating an indoor air quality management plan includes *gaining top administrative support*. School administrative officials should be committed to preparing and carrying out an indoor air quality management plan--this includes providing authority to the IAQ coordinator and the resources to carry out the plan.[1]

EPA Recommended Steps to Activate the Plan

In *Indoor Air Quality Tools for Schools*, EPA recommends several steps to activate the indoor air quality management plan, including the following:[1]

- Identify key members of the indoor air quality team who will work with the IAQ coordinator. These may include teachers, administrative staff, facility operators, building maintenance staff, local health department officials, contract service providers, and parent representatives.

- Distribute action packets to the team members. The action packets provide specific information on indoor air quality relevant to the team members' functions, and allow an audit of the school building to determine potential sources of indoor air quality problems. Team members submit completed checklists to the IAQ coordinator indicating their findings.

- Review the checklists, conduct a walkthrough inspection, and identify priorities for building repair, upgrade, and improved maintenance.

- Get consensus and approvals for repairs, upgrades, and improved maintenance activities and perform these activities as approved.

- Conduct follow-up inspections to determine if repairs, upgrades and improved maintenance have been properly completed and have achieved the desired results.

- Develop and follow a schedule for upcoming activities, such as remodeling, staff changes, and completion of checklists and monitoring activities that affect indoor air quality.

- Maintain good documentation and files for all completed forms, records of repairs or maintenance changes, memos, final reports, and activity reports. Key staff should be made aware of their responsibilities to maintain documentation.

Additional Plan Elements

In addition to the steps listed above, the following plan elements are recommended by the Washington State Department of Health:

- Develop a protocol for handling indoor air quality complaints. The protocol should include designation of key staff for receipt and handling of complaints; follow-up and investigation procedures that should be taken; preparation and use of complaint forms, checklists, and other documentation; procedures for use of outside specialists in resolving indoor air quality problems; communication with other building staff, students, parents, and other interested and affected parties through problem identification and resolution.

- Establish procedures for handling emergency indoor air quality problems. Procedures should include a definition of what constitutes an emergency (such as a spill or release of hazardous substances); response options (for example, building evacuation/spill cleanup, modification of HVAC system operation); assignment of key personnel within the school to address the problem; coordination with local emergency response agencies and private contractors or specialists; identification of special equipment or materials needed for emergency response; training requirements; communication procedures; and documentation requirements. It is essential that a protocol be established for communicating with local emergency response agencies, the health department, the Department of Labor & Industries, building staff, students, parents, the press, and other interested and affected agencies and groups.

- Address proper operation and maintenance of all building systems; precautions for special use areas such as copy rooms, art rooms, science laboratories, vocational arts facilities, locker rooms, pools, general offices and classrooms; purchasing procedures to minimize use of hazardous products; proper storage and use of products; procedures for control of staff and student exposure to contaminants through proper scheduling and notification prior to maintenance, repair and remodeling activities.

- Identify education and training needs for staff, based upon their roles in indoor air quality management. At a minimum, staff should have a basic understanding of the topics addressed in this Manual, their building HVAC system, and the relationship between the HVAC system and building activities. Budgets and schedules should be prepared to meet these education and training needs.

Training and Education

Pages 4-3 and 4-4 emphasized the need for education of school district staff, students, and parents to help maintain good indoor air quality in school buildings. It was recommended that a basic orientation on the Best Management Practices Manual be provided.

All staff, in fact, should have a fundamental understanding of the school's indoor air quality program, how they can help support good management practices, and to whom indoor air quality complaints should be submitted. Staff should also be aware of what to do in an emergency. Teachers working with hazardous materials (for example, in science labs, art rooms, or vocational arts facilities) should have additional training to ensure that practices used in their facilities minimize health and safety risks. School site councils, where they exist, should also have a fundamental understanding of the school's indoor air quality program and how decisions the council may make will affect indoor air quality.

Building maintenance staff and supervisors should have specialized training addressing indoor air quality issues. Such training should include proper building maintenance procedures as it relates to indoor air quality, HVAC system operation and maintenance, hazard communication standards, safety procedures for use of hazardous substances, and emergency procedures.

Communicating with Staff, Students, Parents, and Other Interested Groups

On-going communication with staff, students, parents, the school board, the site council, and other interested and affected groups concerning the school's indoor air quality program is essential. Good communication will help alleviate problems and concerns, and is likely to generate support for the school's efforts to maintain healthy buildings for staff and students. Communicating not only involves sharing information, but listening and responding to concerns and issues raised by these various groups.

Information should be provided during all phases of school development--from siting, design, construction or remodeling--through operation to explain actions the school district is taking to ensure good indoor air quality. It is especially important to provide accurate information in a timely manner.

Information should include identification of the steps students and staff can take to help maintain building air quality. When building maintenance, repairs or remodeling will occur, the school should clearly identify what will be done to ensure those activities are not disruptive, and reduce the potential for exposure of students and staff to indoor air pollution.

Managing Indoor Air Quality Problems

A good program to prevent indoor air quality problems should provide a healthy, productive environment for students and staff. However, some indoor air quality problems may arise, and it is important to give serious attention to how indoor air quality complaints and problems are handled.

Basic steps to address indoor air quality problems reported by staff or students are as follows:

- *Establish a complaint response procedure*. This includes developing a complaint form, developing a log to track complaints, and identifying a key contact person for receipt of complaints. It is critical that complaints be received in a courteous and professional manner, and that follow-up actions be taken promptly and documented.[2,3]

- *Establish communication procedures*. Accurate and timely information concerning the resolution of indoor air quality problems is essential. Once a problem is known to occur, staff and parents should be made aware as soon as possible of the circumstances and what the school is doing to address the problem. Some problems may be of interest to the press. In such a case, it is useful to make sure that a high level administrator or other appropriate representative of the school district is designated as the focal point for communication with staff, students, parents, and the press. It is important that the contact person be accessible to the press, provide accurate information, and not speculate on problems or solutions.[2]

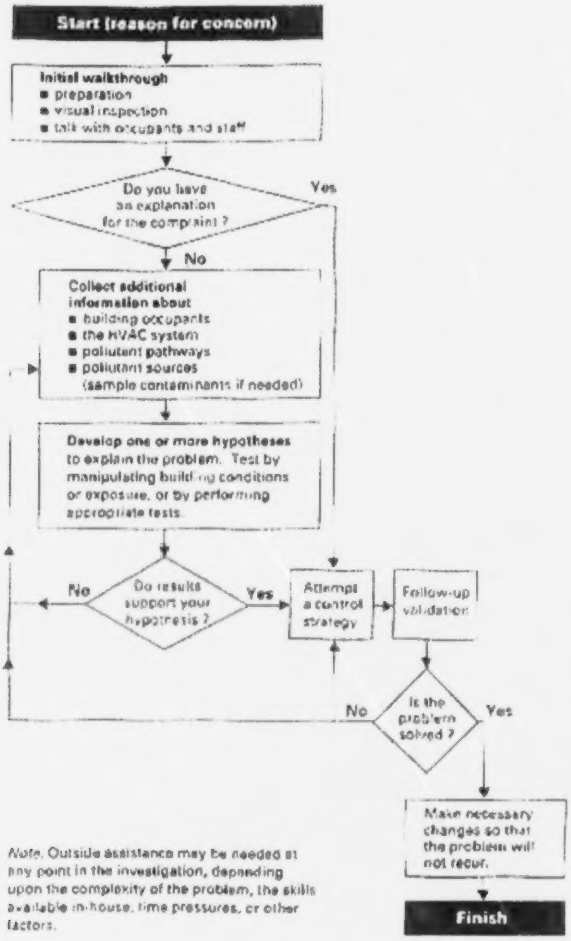
- *Diagnose indoor air quality problems*. Several steps are recommended for diagnosing problems following the receipt of complaints. Initial steps include conducting a walk-through and inspection of the facility and discussion of the problem with staff and students. Further information may need to be gathered to help determine potential causes of the problem, although in some cases no definite causes may be found. However, it may be discovered that performance standards for HVAC system operation, maintenance, or other operational practices are not consistent with the school's indoor air quality plan or the recommendations in this Manual. Practices not consistent with good indoor air quality should be corrected as soon as possible, in any case.

Figure 11-1 illustrates the step-by-step process involved in conducting an indoor air quality investigation.[3]

This Manual is not intended to provide detailed instructions on how to troubleshoot indoor air quality problems. The reader is referred to three specific references which offer very useful recommendations for addressing indoor air quality problems:

- *Building Air Quality--A Guide for Building Owners and Facility Managers* was prepared by the U.S. Environmental Protection Agency, the U.S. Public Health Service, the Centers for Disease Control, and the National Institute for Occupational Safety and Health. Sections Six and Seven of this guide provide detailed information for diagnosing and correcting indoor air quality problems, and the appendices provide useful checklists for complaint documentation and problem investigation.

Figure 11-1: Conducting an Indoor Air Quality Investigation


Start (reason for concern)
Initial walkthrough
■ preparation
■ visual inspection
■ talk with occupants and staff
Do you have an explanation for the complaint ?
Yes
No
Collect additional information about
■ building occupants
■ the HVAC system
■ pollutant pathways
■ pollutant sources
(sample contaminants if needed)
Develop one or more hypotheses to explain the problem. Test by manipulating building conditions or exposure, or by performing appropriate tests.
No
Do results support your hypothesis ?
Yes
Attempt a control strategy
Follow-up validation
No
Is the problem solved ?
Yes
Make necessary changes so that the problem will not recur.
Finish

Note. Outside assistance may be needed at any point in the investigation, depending upon the complexity of the problem, the skills available in-house, time pressures, or other factors.

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- Another excellent guide is *Managing Indoor Air Quality*, by Shirley J. Hansen. This book offers insight into indoor air quality from a manager's perspective, and provides useful recommendations for handling complaints as well as investigating and resolving problems.

- Finally, *Indoor Air Quality Tools for Schools* prepared by EPA provides a helpful problem-solving checklist and wheel for use by school staff.

All three of these documents provide advice on hiring outside professionals (should they be needed) to help resolve indoor air quality problems.

References

1. U.S. Environmental Protection Agency. 1995. Indoor Air Quality Tools for Schools. EPA 402-K-95-001. Washington, D.C. p. 5, 6, 19, 21-23.

2. Hansen, S. 1991. Managing Indoor Air Quality. The Fairmont Press. Lilburn, Georgia. p. 20, 21, 25-29.

3. U.S. Environmental Protection Agency. 1991. Building Air Quality--A Guide for Building Owners and Facility Managers. EPA/400/1-91/033. Washington, D.C. p. 45, 181, 185, 186.

Section Twelve: Other Resources

Various federal, state, and local government agencies as well as private and non-profit organizations may be contacted for further information on indoor air quality.

Federal Government

U.S. Environmental Protection Agency
Region X (Serving Washington, Alaska, Oregon and Idaho)
1200 Sixth Avenue
Seattle, Washington 98101
(206) 553-1200 or
(800) 424-4372

EPA Public Inquiry Phone Numbers:

Indoor Air Quality Clearinghouse: (800) 438-4318
Public Information Center: (202) 260-7751
Toxic Substances Control Act Assistance: (202) 554-1404
National Pesticides Telecommunications Network: (800) 858-PEST
Safe Drinking Water Hotline: (800) 426-4791

National Institute for Occupational Safety and Health
Hazard Evaluation and Technical Assistance Branch
4676 Columbia Parkway
Cincinnati, Ohio 45226
(513) 841-4382
Requests for Information: (800) 35-NIOSH

Occupational Safety and Health Administration
U.S. Department of Labor
200 Constitution Ave. NW
Washington, D.C. 20210
(202) 219-6091

Occupational Safety and Health Administration
Region X (Serving Washington, Alaska, Oregon and Idaho)
U.S. Department of Labor
1111 Third Ave., Suite 715
Seattle, Washington 98101
(206) 553-5930

Consumer Product Safety Commission
Washington, D.C. 20207-0001
(800) 638-2772

Consumer Product Safety Commission
P. O. Box 21027
Seattle, Washington 98111-3027
(206) 553-5276

State Government

Washington State Department of Health
Office of Toxic Substances
P.O. Box 47825
Olympia, Washington 98504-7825
(360) 586-5401

Washington State Department of Health
Office of Community Environmental Health Programs
P.O. Box 47826
Olympia, Washington 98504-7826
(360) 586-4496

Washington Poison Center
P.O. Box 5371, CG-09
Seattle, Washington 98105-0371
(206) 526-2121 or (800) 732-6985

Washington State Energy Office
P. O. Box 43169
Olympia, Washington 98504-3169
(360) 956-2000

Washington State Energy Office
1212 North Washington Street, Suite 106
Spokane, Washington 99201
(509) 324-7980

Washington State Energy Office
914 East Jefferson
Seattle, Washington 98122
(206) 296-5640

University of Washington
Field Research and Consultation Group
Department of Environmental Health, XD-41
Seattle, Washington 98195
(206) 543-7911

Washington State University
Cooperative Extension Service
Urban IPM Clearinghouse
Center for Urban Horticulture
University of Washington, GF-15
Seattle, Washington 98195
(206) 205-8616

Washington Department of Labor & Industries

The Department of Labor & Industries' field offices are available to provide workplace consultation or address compliance issues. Offices are located in Everett, Kennewick, Longview, Mount Vernon, Seattle, Spokane, Tacoma, Tukwila, Tumwater, Vancouver, Wenatchee, and Yakima.

Local Government

There are a variety of local agencies that may provide information and assistance concerning indoor air quality issues. These agencies include local health, building and construction, planning, and fire departments. Regional air pollution control authorities may also be contacted for information.

Private/Non-Profit

Air-Conditioning and Refrigeration Institute
4301 N. Fairfax Drive, Suite 425
Arlington, Virginia 22203
(703) 524-8800

American Conference of Governmental Industrial Hygienists
1330 Kemper Meadow Drive
Cincinnati, Ohio 45240
(513) 742-2020

American Industrial Hygiene Association
2700 Prosperity Avenue, Suite 250
Fairfax, Virginia 22031
(703) 849-8888

National Air Duct Cleaners Association (NADCA) Headquarters
1518 K Street NW, Suite 503
Washington, D.C. 20005
(202) 737-2926

American Society of Heating, Refrigerating and Air-Conditioning Engineers, Inc. (ASHRAE)
1791 Tullie Circle NE
Atlanta, Georgia 30329
(404) 636-8400

American Society for Testing and Materials
1916 Race Street
Philadelphia, Pennsylvania 19103
(215) 299-5571

American Lung Association
1740 Broadway
New York, New York 10019
(800) LUNG-USA

American Lung Association of Washington
2625 Third Avenue
Seattle, Washington 98121
(206) 441-5100

Publications

Readers are encouraged to review other indoor air quality documents referenced in this Manual. Publications available from the U.S. Environmental Protection Agency include *Indoor Air Quality Tools for Schools*, and *Building Air Quality--A Guide for Building Owners and Facility Managers*. These and other documents may be obtained by contacting the EPA Region X in Seattle, at (206) 553-1200 or (800) 424-4372.

The State of Maryland Department of Education offers a series of school indoor air quality publications. For information contact:

Maryland State Department of Education
School Facilities Branch
200 West Baltimore Street
Baltimore, Maryland 21201-2595
(410) 333-2508

For lists of safer art and craft materials, the following organizations may be contacted:

Art and Craft Materials Institute
100 Boylston Street
Suite 1050
Boston, Massachusetts 02116
(617) 426-6400

Center for Safety in the Arts
5 Beekman Street
New York, New York 10038
(212) 227-6220

Getting Rid of Hazardous Materials

Many products used to repair or maintain a school, or used in laboratories, shops, or other classrooms may be hazardous and contribute to poor indoor air quality. These products include certain paints, solvents, adhesives used in building repair and maintenance, chemicals from science laboratories, and certain art supplies.

If these products will not be used and disposal is necessary, proper precautions should be used. Some materials and empty containers may be safely and legally disposed in the municipal solid waste stream. Other materials may require handling and disposal as hazardous waste, with management services provided by local agencies or private waste management contractors.

Before disposing of any material which may be hazardous, the school district should contact the regional office of the Washington Department of Ecology, the local health department, or the local hazardous waste management coordinator for the city or county to determine appropriate reuse, recycling, or disposal methods for such materials.

Some materials which are no longer usable by the school district may be given away for reuse by another organization or business. For further information on material exchange, contact the following organizations:

Pacific Materials Exchange
S. 3707 Godfrey Boulevard
Spokane, Washington 99204
(509) 623-4244

IMEX (Industrial Materials Exchange)
172 20th Avenue
Seattle, Washington 98122
(206) 296-0188

APPENDIX A

Washington State Department of Health
Indoor Air Quality Survey

Please return this form to: Richard Ellis, Building 2, Airdustrial Center, P.O. Box 47826, Olympia, WA 98504-7826
Phone: (360) 586-4496 Fax: (360) 664-3071

Health

Washington State Department of Health
School Indoor Air Quality Survey

School District____________________ESD#________
School Name____________________Address____________
City________________Zip_______ - __________
Name of Person Competing Form________________Title____________
Work Phone ( ) __________ Fax ( ) __________

1. Has your school been built or remodeled since 1989? ☐ Yes ☐ No
2. Has your school experienced any indoor air quality problems since it was built or remodeled? ☐ Yes ☐ No

Please complete the following questions only if you have answered "Yes" to item 2.

3. If item 2 was answered 'yes', did the problem(s) occur...
   (a) ☐ During construction/remodeling? ☐ After construction/remodeling?

   (b) ☐ During Fall ☐ During Winter ☐ During Spring

   (c) ☐ A.M. ☐ Mid-day ☐ P.M.

4. Which group(s) of people were affected?
   ☐ Students ☐ Teachers ☐ Office Staff ☐ Custodial ☐ Shop/Lab
   ☐ All ☐ Other (check all that apply)

5. (a) Was an investigation conducted? ☐ Yes ☐ No
   (b) If item 5(a) was answered "Yes", was the investigation conducted by
   ☐ School Officials ☐ L & I ☐ Consulting Firm
   ☐ Local Health ☐ Other (check all that apply)
   (c) Was the cause(s) of the problem identified? ☐ Yes ☐ No
   Please specify cause(s):____________________
   ____
   (d) What remedial action(s) were taken"____________________
   ____
   (e) Did this solve the problem?____________________

6. Was any part of the school closed/evacuated? ☐ Yes ☐ No
   If "Yes" for how many days? ________

7. Please (roughly) estimate the cost to the District that the problems(s) caused in staff time, IAQ investigation, corrective actions(s) and time loss claims: $__________

8. What key things would you suggest to help improve and prevent future problems?

Washington State Department of Health
School Indoor Air Quality Survey Results
December 29, 1994

1. Has your school been built or remodeled since 1989? Yes 62 No 72

2. Has your school experienced any indoor air quality problems since it was built or remodeled?
   Yes 33 No 99

3. If item 2 was answered "Yes", did the problem(s) occur...
   (a) During construction/remodeling 5 After construction/remodeling? 25
   (b) During Fall? 22 During Winter? 19 During Spring? 21
   (c) A.M.? 21 Mid-day? 23 P.M.? 20

4. Which group(s) of people were arffected?
   Students? 21 Teachers? 24 Office Staff? 12 Custodial? 6..
   Shop/Lab? 3 All? 10 Other: 0

5. (a) Was an investigation conducted? Yes 27 No 4

   (b) If item 5(a) was answered "Yes", was the investigation conducted by...
   School Officials? 24 L & I? 5 Consulting Firm? 12
   Local Health Department? 5 Other? 1

   (c) Was the cause(s) of the problem identified? Yes 17 No 3
   Please specify cause(s): See attached.

   (d) What remedial actions(s) were taken? See attached.

6. Was any part of the school closed/evacuated? Yes 7 No 12
   If "Yes", for how many days? Average: 20.9 days Range: 1-60 days

7. Please (roughly) estimate the cost to the District that the problem(s) caused in staff time, IAQ investigation,

   corrective action(s) and time loss claims? Average: $134,750 Range: $500-900,000

8. What key things would you suggest to help improve and prevent future problems? See attached.

5(c). Causes?	5(d). Remedial Actions?
Mastic remover	Too numerous to list
Too little supply air	Replaced central air with univents
Too much hot air, too little cold; old, old univents	Changed DDC control
Exhaust dampers won't open	New dampers and booster fan
Plum draw vents not hooked up	Connect plumbing vents
Dirty HVAC and laminator VOC's	Add fans in workroom, change filters more often
No vent for library heater	Vent furnace
Lighting ballast smoke	Replace ballast
Outdoor smoke	Put in high efficiency filters
Carpet glue in gym, paint VOC's, dust, tile glue	Closed gym
Carpet adhesive, air circulation, VOC's	Baked out building and improved circulation
Mildew, mold	Crawl spaces & ducts cleaned, flat roof "pitched"
Dust from heat system ducts	Upgrade and change filters
HVAC computer, valves, UMTs	Replaced faulty HVAC equipment
Faulty heating equipment	Replaced faulty equipment
Science labs not properly ventilated	Fixed lab ventilation
Building too hot on south side	Increased air flow
Insufficient air flow and cooling	No action take due to lack of money
Poor air flow	Reduct and change intake
Chemical and gas spills, broken exhaust	Cleaned up spills and fixed fan
Mold and mildew	Increased venting
Broken heat pump	Replaced heat pump
Bus exhaust sucked into HVAC	Modified air intak in bus area
"Stuffy" feeling	Increased fan speeds
Carpet smell	Moved children
Wet insulation around steam pipe in wall	Closed room
Laminator fumes and copy machines	Nothing, cost too high

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8. SUGGESTIONS:

- Eliminate toxics in construction
- Simplify designs of HVACs
- Provide natural ventilation, i.e. window
- System check before school startup in fall
- Add fans in dead air spaces
- Change filters in HVAC more often
- Need better training on VAC maintenance
- Need better training on use of cleaning chemicals
- Make sure units are designed properly
- Need appropriate and timely response when "event" occurs
- Better filtering systems needed where students are asthmatic or sensitive

  - should be able to remove pollen and smoke
- Use water base carpet and tile glues
- Choose carpet that has been tested and is "low toxic"
- Choose materials carefully and do bake out and curing before school starts or is occupied
- Establish regular cleaning and maintenance of duct work and furnace
- Keep maintenance up to "standards"
- Never take safety for granted - Cusick High School
- Do not design building with air intakes by buses
- HVAC systems need to be balanced
- Don't lay carpet in student areas on school days
- Better exhaust venting needed in office copy/laminator rooms

APPENDIX B

HVAC Checklist

Washington State Department of
Health

HVAC Checklist

File Number________________________ Date: ____/____/____

Building: ________________________ Location/Address________________________

Inspector: ________________________

Mechanical Room

- Clean and dry: YES NO Stored refuse or chemicals: YES NO

Major Mechanical Equipment

- Preventative Maintenancc e Plan in use? YES NO (If "No" explain below).

- Control System and type________________________
- System Operation________________________ Date of last calibration: ____/____/____

- Boiler Condition: GOOD FAIR POOR Rated BTU input ________________
- Once square inch free area per 2,000 BTU input? YES NO
- Fuel or combustion odors? YES NO

- Cooling Tower performance GOOD FAIR POOR
- Clean with no leaks or overflow? YES NO Slime/Algae growth? YES NO
- Type of biocide ____________ Biocide Working? YES NO
- Spill Plan in place? YES NO Dirt separator working? YES NO

- Chillers/Refrigerator leaks? YES NO Condensation problems? YES NO
- Waste Oil and refrigerant properly stored and disposed of? YES NO

Air Handling Unit

Unit Identification:________________________ Area Served:________________
Outdoor air intake location:________________ Date tested and balanced: ____/____/____
Design Total cfm: ________________ Outdoor air (O.A.) cfm: ________________
Minimum % O.A. (damper setting): ____________ Minimum cfmO.A.:________________
Condition of dampers and controls: GOOD FAIR POOR Date ____/____/____
Current damper control settings: Date ____/____/____ Time: ________ Mode: ________
Damper control sequence: ________________________
Nearby contaminant sources? YES NO (Describe below)
Bird screens in place and unobstructed? YES NO

Comments: Explain any problem or malfunction. Attached additional sheets if necessary.

- Fan Condition GOOD FAIR POOR Control Sequence ______________________________
  - Indicated temp: supply ______ mixed air _______ return air _______ outdoor air _________
  - Actual temp: supply ______ mixed air ________return air _______ outdoor air _________
- Coil Condition GOOD FAIR POOR Controls____
  - Heating fluid discharge temp__________AT________cooling fluid discharge temp_____________
- Humidifier Condition GOOD FAIR POOR Conditioner type_____________________________
  - Slime, visible growth or mineral deposits? YES NO Biocide type used_____________________

Distribution System

Zone or Room	**System Type**	**Supply Air**		**Return Air**		**Power Exhaust**		
		ducted/ unducted	**cfm**	**ducted/ unducted**	**cfm**	**cfm**	**control**	**serves (e.g.toilet)**

- Adequate access? YES NO Ducts and coils clean and unobstructed? YES NO

  Note location of blocked air paths, diffusers or grilles in box at bottom of the page.
  - Air volume correct? YES NO Air supply OK NO return OK NO transfer OK NO
  - exhaust OK NO makeup OK NO Any improper openings in plenums YES NO
  - Drain pans clean YES NO Visible growth or odor YES NO

Filters

Location	**Type/Rating**	**Size**	**Date last Changed**	**Condition/Date**

Occupied Space

Thermostat types____

Humidistat/Dehumidistat types____

Control T= Therm. H= Humidistat	**Location**	**What does it control (e.g. radiator, AHU-3)?**	**Set Points**		**Measured Temperature**	**Potential Problem?**	**Date/Time Inspected**
			Summer	**Winter**			

Explain any potential problems with thermal comfort, air circulation, malfunctioning equipment or sources of odors or contaminants in box below.

Comments: Explain any problem or malfunction. Attach additional sheets if necessary.